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EXPEDIENT AM AND FM BROADCAST ANTENNAS

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The use of expedient antennas by broadcast stations, response of station personnel to an emergency and characteristics of antenna systems are examined. Expedient antennas are proposed for AM and FM stations and procurement specifications are presented.

A monograph on the construction of expedient antennas from available materials is included.

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5. Radiation Pattern						
6. Transmitter Efficiency						
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DETACHABLE SUMMARY

EXPEDIENT AM AND FM BROADCAST ANTENNAS

FINAL REPORT

By:

Donald E. Pauley

For:

DEFENSE CIVIL PREPAREDNESS AGENCY

Washington, D. C. 20301

DCPA Review Notice

This report has been reviewed in the Defense Civil Preparedness Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Defense Civil Preparedness Agency.

NOVEMBER, 1973

GAUTNEY & JONES COMMUNICATIONS, INC.

FALLS CHURCH, VIRGINIA

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RECOMMENDATIONS

1. Distribute one copy of the expedient antenna construction monograph to all AM broadcasting stations.

2. Supply a horizontal wire expedient antenna package, appropriate for the station's frequency and power, to each AM station in the Radio Broadcast Station Protection Program.

3. For selected stations in major metropolitan areas, supply a top-loaded expedient antenna using a quick-erect tower custom designed for each installation.

4. Supply an expedient FM antenna package to each FM station in the Radio Broadcast Station Protection Program.

5. As a follow-on to this present work, fabricate and field test sufficient prototype expedient antennas to confirm the concept and verify installation procedures and operational effectiveness of the proposed packages.

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GAUTNEY & JONES
CONSULTING RADIO ENGINEERS

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I. INTRODUCTION

1.0 GENERAL

Broadcasting stations participating in the Defense Civil Preparedness Agency Radio Broadcast Protection Program have the mission to disseminate emergency information to the public. To fulfill this mission it is essential that the stations remain operational during the emergency. Where necessary DCPA through the Radio Broadcast Protection Program has provided radiation shelters, emergency power, alternate programming facilities, and alternate two-way communications equipment to ensure operational capability of these stations. A means is needed for restoring the most exposed element of the radio station, the antenna system.

Most antenna systems are designed to survive routine environmental disturbances. However, the system can be destroyed by extreme disturbances which may accompany natural or nuclear disasters.

The purpose of this study, conducted under Contract DAHC20-73-C-0160, is to develop low cost techniques and packages using types of equipment which can serve as expedient antennas for AM and FM stations in the event of destruction of the regular towers.

1.1 OBJECTIVES

The objective of this study is to select techniques and desirable equipment that will enable broadcasting stations in the Defense Civil Preparedness Agency Radio Broadcast Protection Program to rapidly restore broadcasting capability in the event of destruction of the regular antenna system. To effectively meet the objective, two approaches are considered.

First, a monograph of techniques for constructing expedient antennas using available materials has been developed. The purpose of the monograph is to enable station technicians with average qualifications to construct expedient antenna systems under emergency conditions in minimum time utilizing available materials.

The second, and the principal, approach is a family of standard package antenna systems which DCPA can supply to stations. The objective of this approach is to provide materials and directions to restore service in the shortest possible time. The time required to deploy a packaged antenna is expected to be much less than the time required to construct an expedient from available materials.

1.2 SCOPE OF WORK

A. General - The Contractor, in consultation and cooperation with the Government, shall furnish the necessary facilities, personnel, and such other services as may be required to develop and determine the effectiveness of various low-cost techniques and equipment for expedient antennas. The work and services shall be performed as specifically provided herein.

B. Specific Work and Services - The Contractor shall perform specific work and services as follows:

1. Develop and determine the effectiveness of various low-cost techniques and equipment for expedient antennas to be used by AM and FM radio broadcasting stations.

2. Develop a package plan suitable for inclusion in the Defense Civil Preparedness Agency's Radio Broadcast Station Protection Program.

1.3 OPERATIONAL REQUIREMENTS

The operational requirements of an expedient antenna system are formulated. One of the principal goals of this task was to determine the value function of deployment time for an expedient antenna. The value function is based on the emergency communications mission assigned to broadcasting stations to disseminate information. Other significant operational characteristics are:

. . . power capacity

. . . signal coverage

. . . survivability

. . . frequency

. . . interaction with normal antenna

1.4 EVALUATION OF ANTENNA TYPES

An evaluation of types of antenna systems has been conducted using the operational requirements as the criteria. The evaluation includes, as a minimum, the following types:

. . . vertical monopole

. . . flat-top

. . . horizontal wire

. . . slant wire

. . . balloon supported vertical wire

1.5 ANALYSIS AND DESIGN

For each antenna type selected as suitable, a detailed technical analysis has been conducted. Design plans have been prepared for a horizontal wire AM antenna and an FM antenna. The plans include:

. . . parts list

. . . anticipated cost

. . . deployment requirements

. . . survivability

. . . signal coverage

. . . frequency range

. . . power capacity

1.6 EXPEDIENT ANTENNA MONOGRAPH

A monograph of techniques for constructing expedient antenna systems has been developed. The techniques are presented in sufficient detail to enable a technician with average qualifications to deploy an expedient antenna within a reasonable time using available materials. The monograph includes both the antenna and the matching system.

II. EVALUATION CRITERIA

2.0 MISSION

In evaluating the utility of an expedient antenna system it is necessary to consider the mission of broadcasting stations during an emergency, the response procedures of personnel, the environmental disturbance that may destroy an antenna system, and the radiation characteristics of antennas.

The mission of broadcasting stations has been defined as dissemination of information. Warning is to be provided by other systems. The implication is that broadcasting stations will not be of primary importance at the instant of a disaster but may be of critical importance during recovery.

2.1 RESPONSE TIME

A station cannot respond to an emergency immediately. On a worst case analysis it is assumed that the emergency occurs without warning. The typical sequence for non-attack emergency activation is: determination by local government that an emergency exists; notification of stations; decision by the station to participate; mobilization of station personnel; preparation of emergency information by local government; broadcast of emergency information. Contrary to the optimistic claims of broadcasters and local government officials, all of the activation steps consume substantial time. It is very seldom that emergency information will be broadcast within 10 minutes after the occurrence of a disaster. The average time lag is around 30 minutes with delays of more than an hour not uncommon if the station is operating at the instant of the disaster. If the disaster occurs after the station has signed off the time delay may be much greater. Figure 2.1 shows an assumed probability density

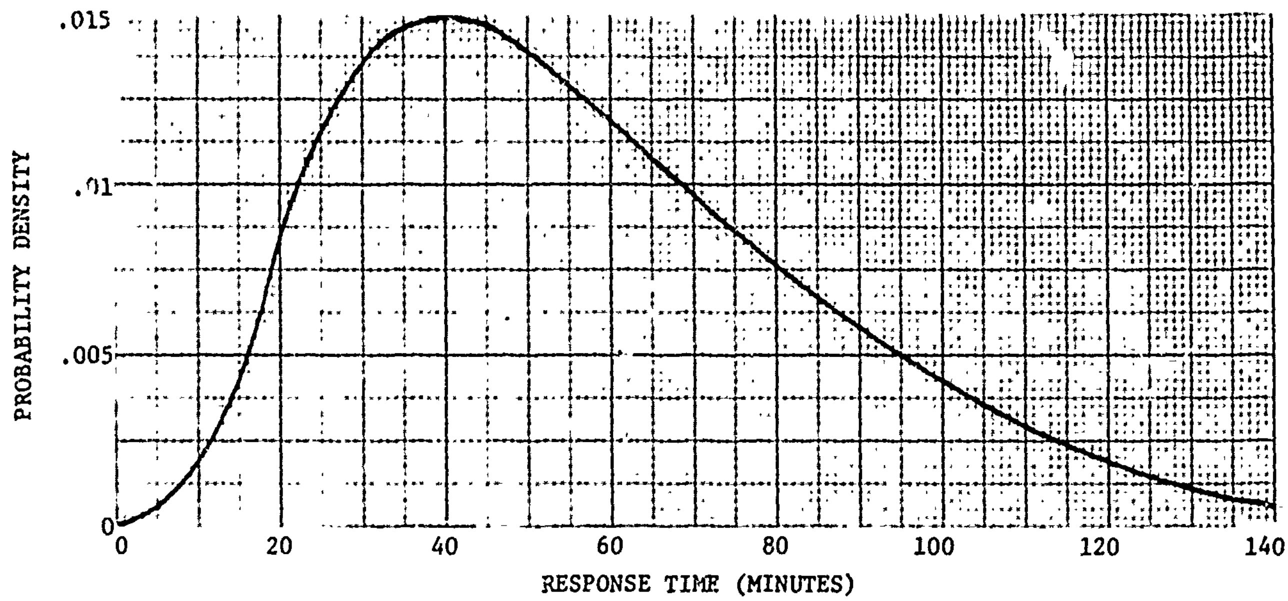


FIGURE 2.1

PROBABILITY DENSITY FUNCTION FOR EMERGENCY RESPONSE TIME
FOR BROADCASTING STATIONS AND LOCAL GOVERNMENT

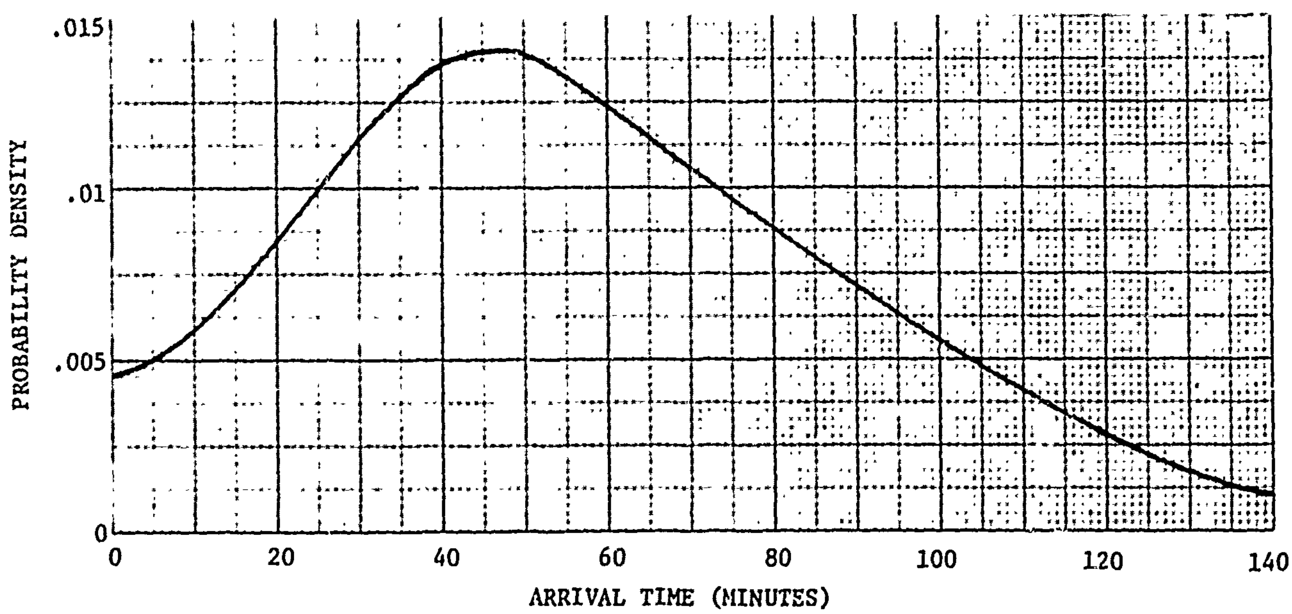


FIGURE 2.2

PROBABILITY DENSITY FUNCTION
FOR TECHNICIAN ARRIVAL TIME AFTER EMERGENCY

curve for the time lag before emergency information broadcasting is initiated. This curve is not based on rigorous quantitative data but does reflect the experience of several stations in responding to emergencies.

If the station's antenna is destroyed during the disaster, an expedient antenna must be deployed before emergency information can be broadcast. A typical sequence for expedient antenna deployment is: arrival of technician; survey of damage; decision of method of deployment; deployment; adjustment of matching network; resumption of broadcasting. Since many stations operate with remotely controlled transmitters, there may be a substantial delay before a technician is available at the transmitter site. Figure 2.2 shows an assumed probability density curve for the time before a technician is available.

After assessing the extent of the damage, the technician must decide the technique to use in deploying an expedient antenna. The options may be to use a surviving tower, to deploy a packaged expedient antenna, or to construct an antenna from available materials. The average time from the destruction of the normal antenna to the start of deployment of an expedient is about 30 minutes for a competent, conscientious technician. The time required to actually deploy the expedient antenna will depend on the type of antenna, the competence of the technician, and the degree of advance planning.

2.2 ENVIRONMENTAL EFFECTS

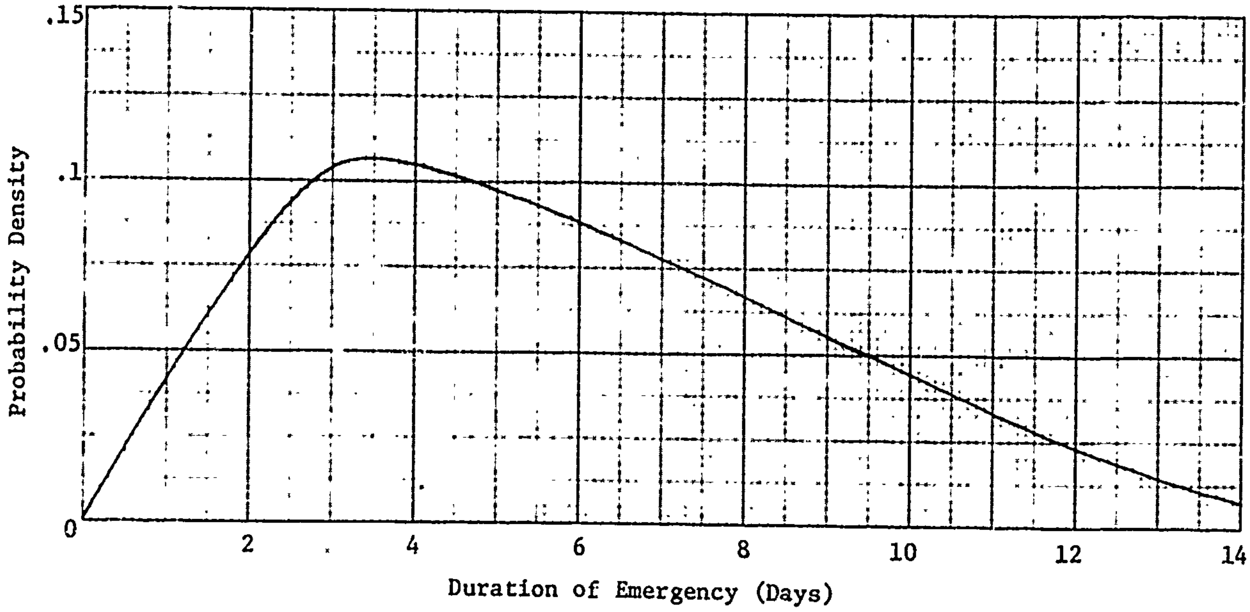
An expedient antenna need be deployed only after the destruction of the normal antenna. For the purposes of this study, only those destructions occurring during an emergency will be considered. It is assumed that destruction is the result of an extreme environmental disturbance such as a tornado, hurricane, earthquake, or weapons induced shockwave.

While each emergency is unique, some general characteristics can be identified. An emergency consists of three phases: imminent, destructive and recovery. During the imminent phase normal services and communications are available. Warning information may be available and may be disseminated by broadcasting stations and other warning systems. During the destructive phase the environmental disturbances are too severe to permit effective utilization of emergency information.

The critical need for emergency information is during the recovery phase immediately following the destructive phase. The environmental disturbances of the destructive phase are to be expected to continue with decreasing severity into the recovery phase. Movement and access to supplies may be impaired due to destruction of roads and transportation facilities.

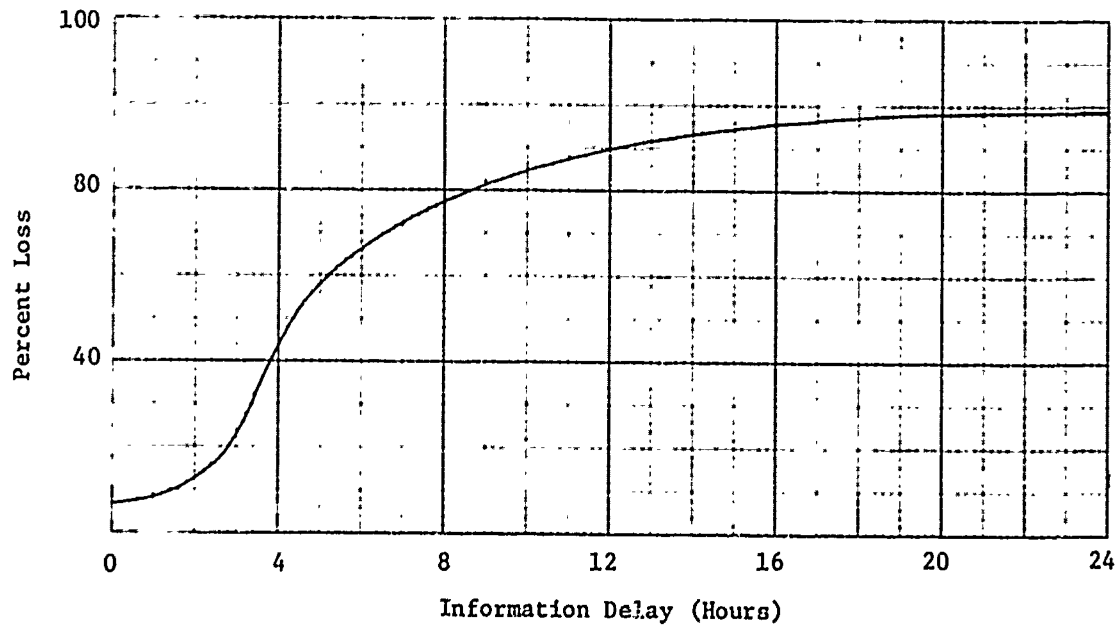
Duration of the recovery phase will be variable but will usually be much longer than the preceding phases. Figure 2.3 shows the assumed probability density distribution for the recovery time. The recovery phase is assumed to terminate when restrictions on supplies and movement are insignificant.

A substantial portion of the losses during an emergency occur during the recovery phase due to isolation of individuals and uncoordinated relief operations. Perfect communications could prevent most of these losses. Figure 2.4 shows the assumed preventable loss that would occur if dissemination of emergency information is delayed.



PROBABILITY DENSITY FUNCTION FOR DURATION OF EMERGENCY (RECOVERY PHASE)

FIGURE 2.3



LOSS RESULTING FROM DELAY OF EMERGENCY INFORMATION

Figure 2.4

2.3 RADIATION CHARACTERISTICS

The area in which a radio station can disseminate information is a function of radiated power, antenna system directivity, and propogation characteristics. Radiated power is the product of input power and antenna efficiency. Thus, for a fixed transmitter power, reduction in efficiency is equivalent to reduction in power. The efficiency of a normal antenna system is about 90%.

Directivity of an antenna increases the signal in some directions and suppresses it in other directions. In AM broadcasting, a vertical antenna has no directivity while a horizontal or a slant-wire antenna has pronounced directivity. Directivity may be used to increase the coverage in desired areas if the suppression can be oriented towards areas where coverage is not necessary.

FM antennas, except in a few special cases, are essentially non-directional.

The most significant propagation factors for AM stations are soil conductivity and frequency. Figure 2.5 is a tabulation of distances to the 0.5 mv/m contour for selected powers, frequencies, and soil conductivities. The 0.5 mv/m contour is considered to render adequate service in the absence of interference.

For an FM station the most significant propagation factor is height of the transmitting antenna above average terrain. Figure 2.6 shows the distance to the 1 mv/m contour for selected powers and heights. The FM 1 mv/m contour is roughly the equivalent of the AM 0.5 mv/m contour in that it represents the approximate extent of FM coverage in the absence of interference.

FIGURE 2.5

DISTANCE TO 0.5 mv/m CONTOUR
AM STATIONS

frequency - 600 kHz

conductivity

POWER	1	4	8	20
250	17.5	37	53	82
1000	27	57	85	135
5000	39	79	120	192
10000	45	90	136	218
50000	66	128	184	285

frequency = 1000 kHz

conductivity

POWER	1	4	8	20
250	12	24	35	58
1000	17.5	32	48	80
5000	26	47	68	114
10000	30	54	78	130
50000	44	76	107	172

frequency = 1600 kHz

conductivity

POWER	1	4	8	20
250	8.5	14.5	21	36
1000	12	20	28	47
5000	18	28	40	66
10000	21	34	47	76
50000	32	49	68	105

* Power in watts
Conductivity in mmho/m
Distance in miles

FIGURE 2.6

DISTANCE TO 1.0 mv/m CONTOUR
FM STATIONS

HEIGHT ABOVE AVERAGE TERRAIN

POWER	100	300	500	1000
250	5	8	10	15.5
1000	6.5	11.5	14.5	21
3000	8.5	15	18.5	27
10000	11.5	19	24	33
50000	17	27	33	43

* Power in watts
Distance in miles
Height above average terrain in feet

The value function for operating at a particular power level is difficult to assign. Obviously the highest value is to operate with emergency facilities equivalent to the normal facilities. However, coverage at great distances may be of little value. It is tempting to assign values based on a standard service area such as the area within 25 miles of the station, however, low power, high frequency AM stations in areas of low soil conductivity do not normally provide service at distances approaching 25 miles. Also high power, low frequency stations in areas of high soil conductivity may be located more that 25 miles from the principal city.

III EVALUATION OF AM ANTENNAS

3.0 GENERAL

The expedient antenna is to be deployed by a typical station technician following the destruction of the normal antenna. Using the expedient antenna the station is to provide service to the surrounding communities. In order to provide adequate service the expedient antenna must be at least a moderately effective radiator.

Any conducting object can theoretically be considered as an antenna. However, most configurations are extremely inefficient. The objective of this study is to examine the electrical and physical properties of antenna systems that a typical station technician could deploy within a short period of time.

The basic unit of measurement in antenna systems is the wavelength λ. The wavelength is related to the station frequency by:

$$\lambda = v/f$$

Where v is the velocity of propagation

f is the frequency in Hz

The velocity of propagation is approximately equal to the speed of light.

If the frequency is expressed in MHz and the wavelength in feet the following relationship can be used:

$$\lambda = 984/f$$

Figure 3.1 graphically shows the relation between frequency and wavelength.

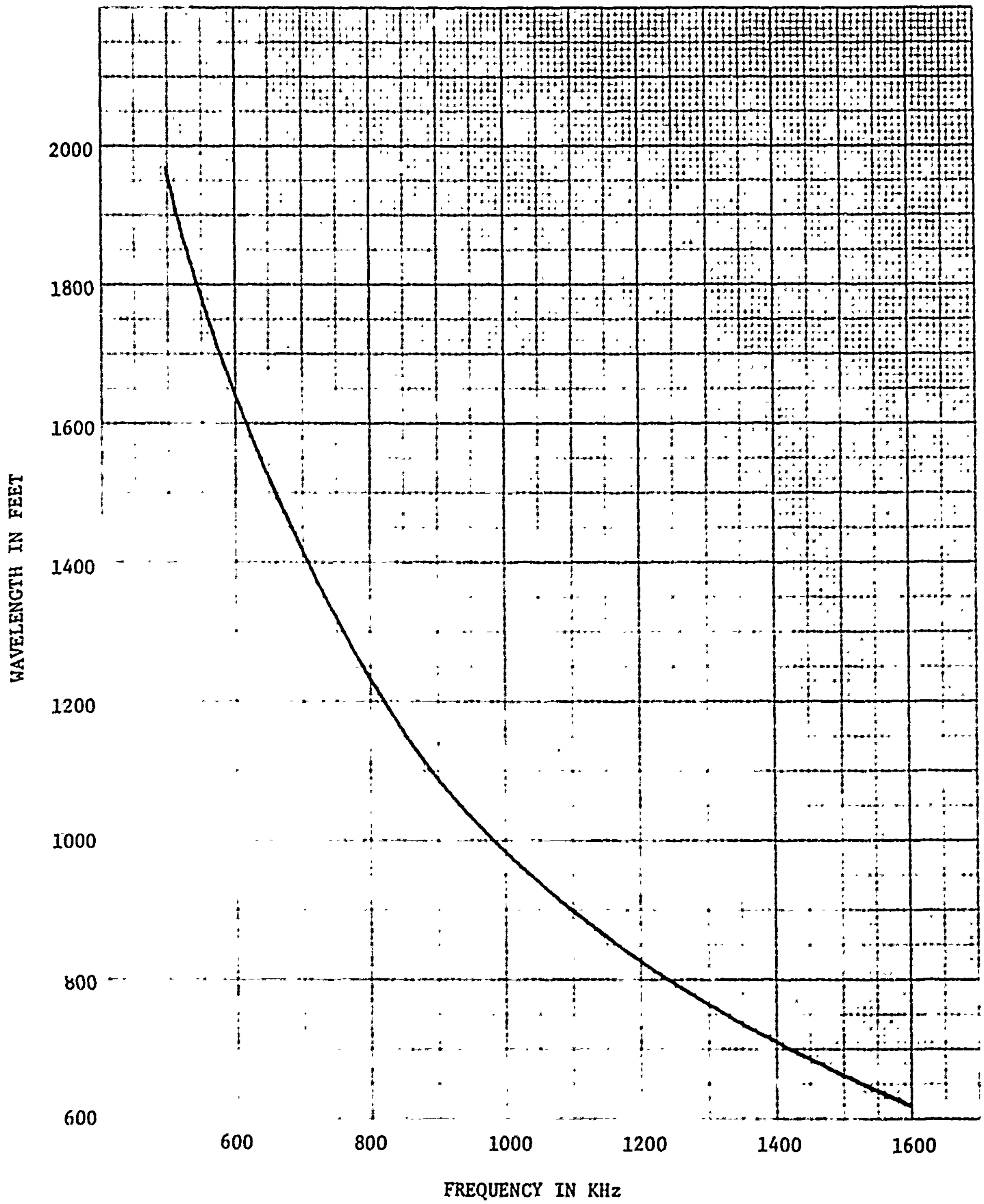


FIGURE 3.1

WAVELENGTH VS FREQUENCY

The measurement unit can also be expressed in electrical degrees with one wavelength (one full cycle) equal to 360°. Thus the most commonly used AM broadcast antenna may be described as a 1/4 wavelength antenna, a 90° antenna or by the height in feet corresponding to 1/4 wavelength at the operating frequency.

3.1 ELECTRICAL PROPERTIES

The electrical properties of interest are related to the capability of the antenna system to provide communications. These properties are efficiency, input impedance, and radiation pattern.

3.1.1 EFFICIENCY

The efficiency of an antenna system may be expressed as the percentage of transmitter power that is radiated. Obviously a high efficiency is desirable, and the efficiency of a normal broadcasting antenna is approximately 90%.

Antenna efficiency is reduced due to power loss in the system, principal losses being coupling component heating, ground return current and dielectric losses.

Coupling component heating is due to current through an imperfect inductor or capacitor. Since no component is perfect there is always some loss, usually significant only when substantial current flows through a large inductor. For a simple "L" network the coupling loss is approximately:

$$P_{LC} = I_A^2 X_L/Q$$

where I_A is the antenna input current

X_L is the reactance of the inductor

Q is the quality factor of the inductor

The coupling loss cannot be reduced by arbitrarily reducing I_A or X_L since both I_A and X_L are determined by the antenna input impedance.

The loss due to ground current results from an imperfectly conducting ground. The effect can be approximated as a resistance, R_G, in series with the antenna operating above a perfectly conducting ground. The loss is approximately given by:

$$P_{LG} = I_R^2 R_G$$

where I_R is the antenna radiation current

The value of R_G depends on many factors including the ground system, soil type, temperature, soil moisture, antenna height, and local vegetation. Since the expedient antenna will utilize the existing ground system, the value of R_G cannot be controlled.

The dielectric loss is due to imperfect insulators supporting the antenna and can be approximated by a resistance, R_D, shunted across the antenna input. The power loss is approximately given by:

$$P_{LD} = E_A^2 / R_D$$

where E_A is the antenna input voltage

Since most insulators that are used in antenna systems are very good, dielectric losses are important only when the input voltage, E_A, is very large. Corona losses are usually lumped with dielectric losses since both are a function of the voltage.

3.1.2 INPUT IMPEDANCE

The input impedance of an antenna is a complex quantity consisting of resistance and reactance, and is expressed as:

$$Z_A = R_A + jX_A$$

An equivalent circuit of an antenna and coupling system is shown on Figure 3.2. The input impedance is measured at point "A".

The true antenna radiation impedance is:

$$Z_R = R_R + jX_R$$

This impedance is modified by the series ground loss resistance, R_G; the shunt dielectric resistance, R_D; and the shunt base capacitive reactance, X_B. Thus the input impedance is the combination of Z_R, R_G, R_D, and X_B.

Only the element, R_R, contributes to the radiation. The radiated power is:

$$P_R = I_R^2 R_R$$

The antenna input power is:

$$P_A = I_A^2 R_A$$

and the antenna input voltage is:

$$V_A = I_A Z_A$$

For an efficient, well constructed antenna system Z_A is approximately equal to Z_R. The theoretical radiation impedance, Z_R, can be calculated using well established formulas for several simple antenna structures.

3.1.3 RADIATION PATTERN

An antenna system at the surface of the earth radiates energy into

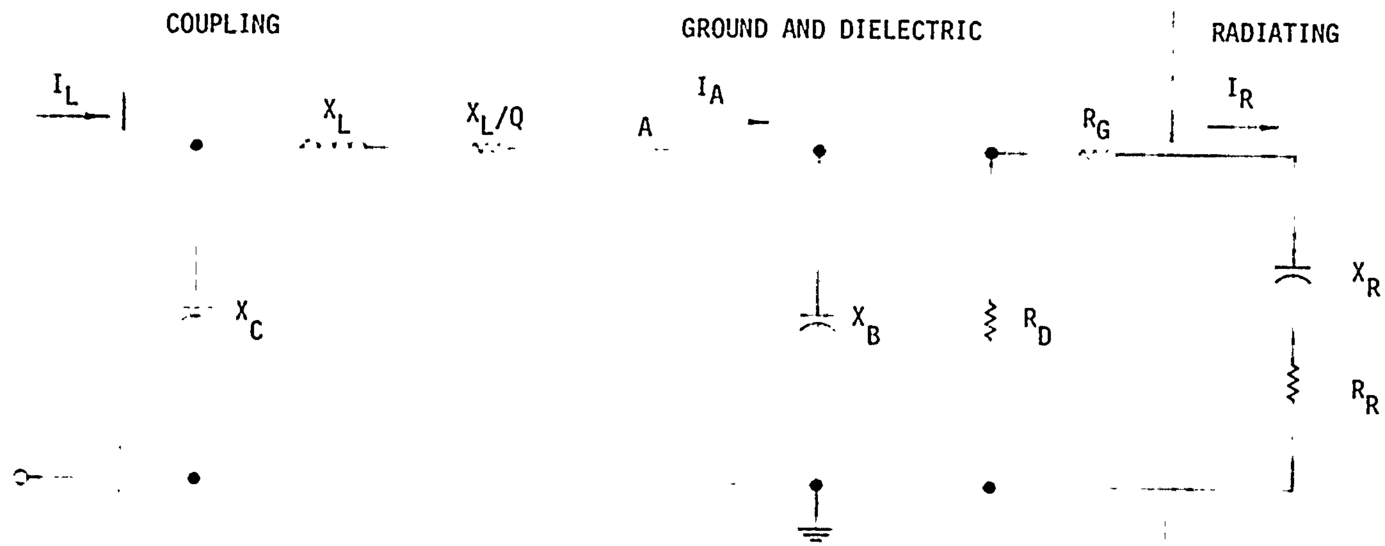


FIGURE 3.2

EQUIVALENT CIRCUIT OF ANTENNA SYSTEM

the entire hemisphere above the surface. The distribution of the radiated energy within the hemisphere is known as the radiation pattern. Only energy radiated in the horizontal plane can be received within about 50 miles of the transmitter, and energy radiated above the horizon is effectively lost.

The radiation pattern is a function of current distribution in the antenna system. Current distribution is determined by the physical configuration and the interaction between elements of the antenna system. An image of any radiator above a conducting ground is reflected in the ground system and this image must be considered as an element of the antenna system. For most antenna systems current distribution and, hence the radiation pattern is determined entirely by the configuration. The complexity of special antennas with modified current distributions preclude their use as expedient antennas.

The maximum radiation from a straight, uniform conductor is perpendicular, or broadside to the conductor. Radiation off the end of the conductor approaches zero. Thus a vertical radiator has a maximum in the horizontal plane and has a non-directional azimuth pattern.

A horizontal radiator near a conducting ground has two deep minima off the ends. Due to the image element the maximum radiation is vertical and radiation in the horizontal plane is reduced.

3.1.4 ANTENNA TYPES

Many different configurations of conductors can be used as antennas with each configuration possessing unique electrical characteristics. For an expedient antenna only relatively simple configurations that can be

deployed in a short time by one technician are practical.

These antennas can be categorized as vertical monopole, non-vertical monopole, top-loaded, and folded unipole.

3.1.4.1 VERTICAL MONOPOLE ANTENNA

The vertical monopole is the most commonly used antenna for AM broadcasting. The radiating structure is a single vertical conductor over a conducting ground system. The theory of the vertical monopole antenna is well developed. Current distribution is approximately sinusoidal.

The radiation resistance, R_R, of a thin vertical antenna is shown on Figure 3.3 and the reactance X_R, is shown on Figure 3.4. The antenna input impedance is modified by the loss resistances and the base capacitance. For very short antennas the resistance is very low and the reactance is very high. This combination results in low efficiency and very high base voltages.

The horizontal radiation pattern is non-directional. The vertical radiation pattern for a short antenna is shown on Figure 3.5. As the height of the antenna is increased radiation in the horizontal plane is increased and radiation above the horizon is reduced. Figure 3.6 shows theoretical radiation in millivolts per meter at one mile for 1000 watts antenna input power, assuming no losses. The radiation from an average antenna with losses is shown as a broken line.

Vertical monopole antennas less than 0.15λ (54°) in height are generally considered impractical due to the low efficiency and the high

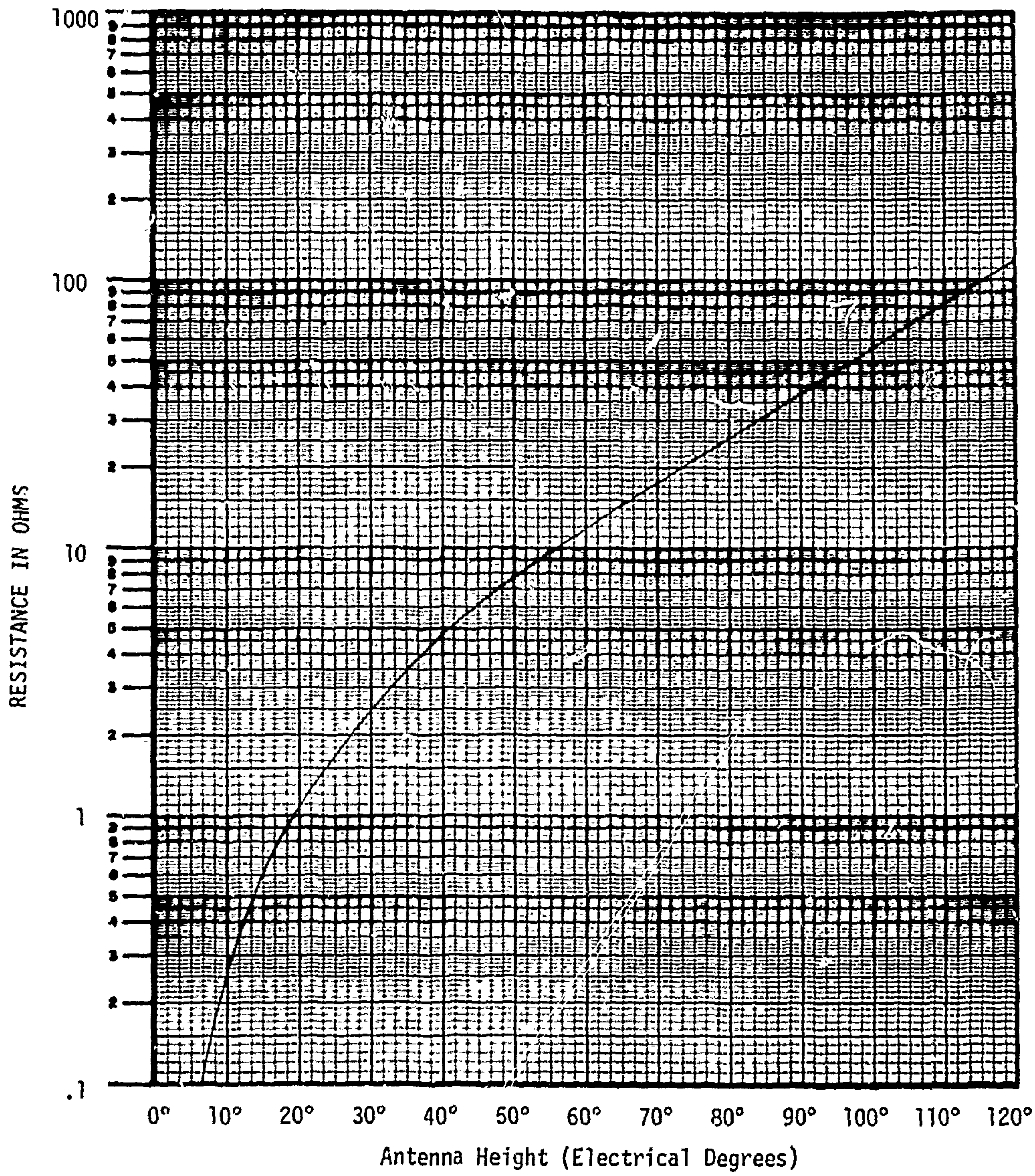


FIGURE 3.3

RADIATION RESISTANCE VERTICAL MONOPOLE

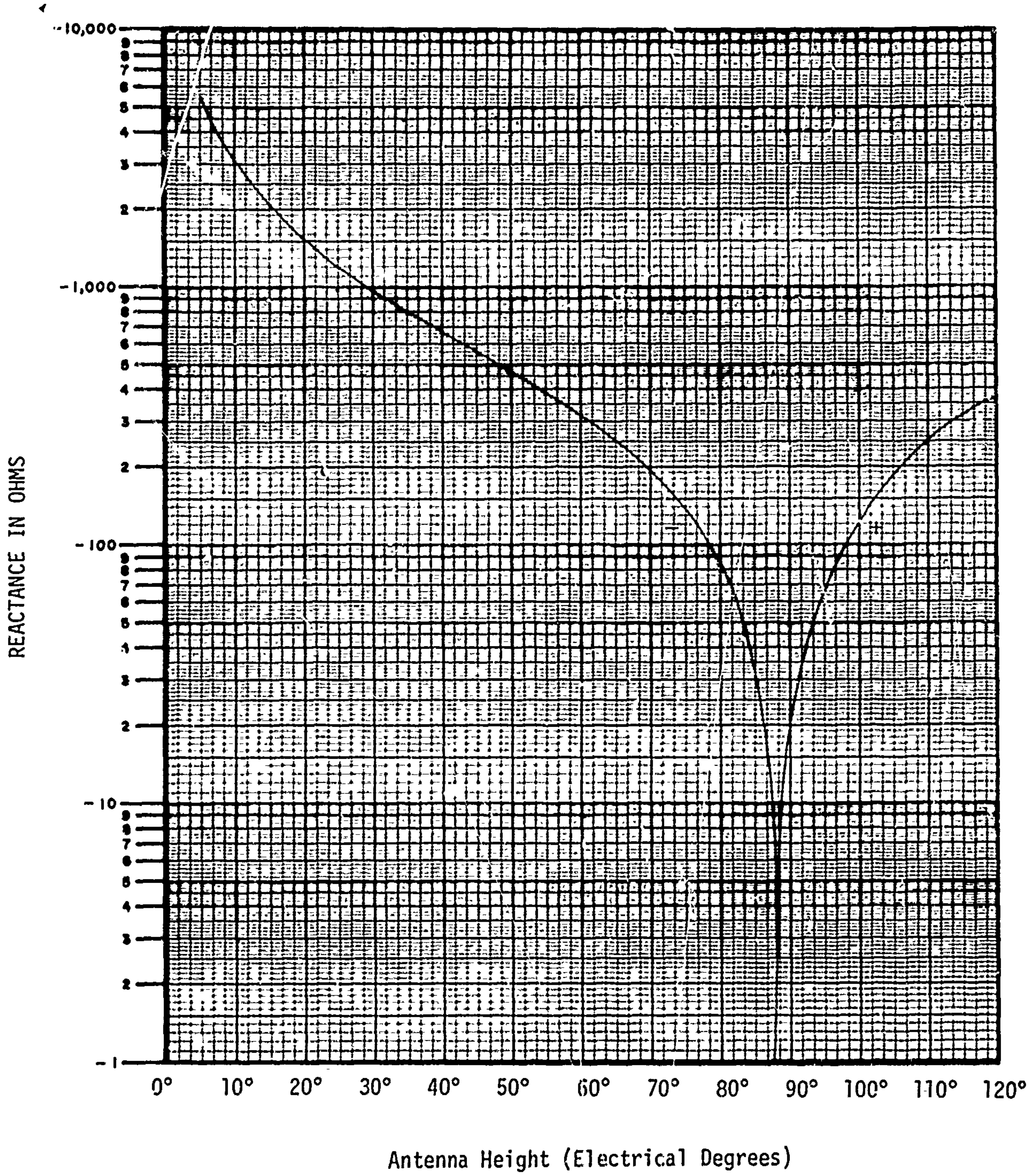
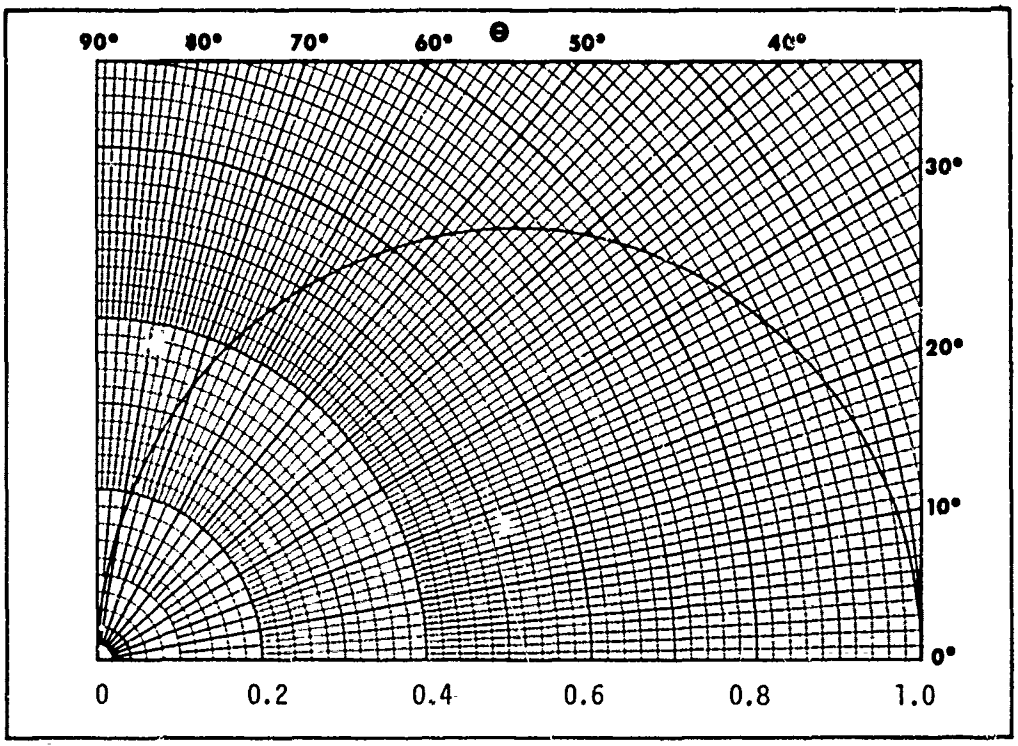


FIGURE 3.4

RADIATION REACTANCE VERTICAL MONOPOLE



RELATIVE FIELD

FIGURE 3.5

VERTICAL RADIATION PATTERN
SHORT MONOPOLE ANTENNA

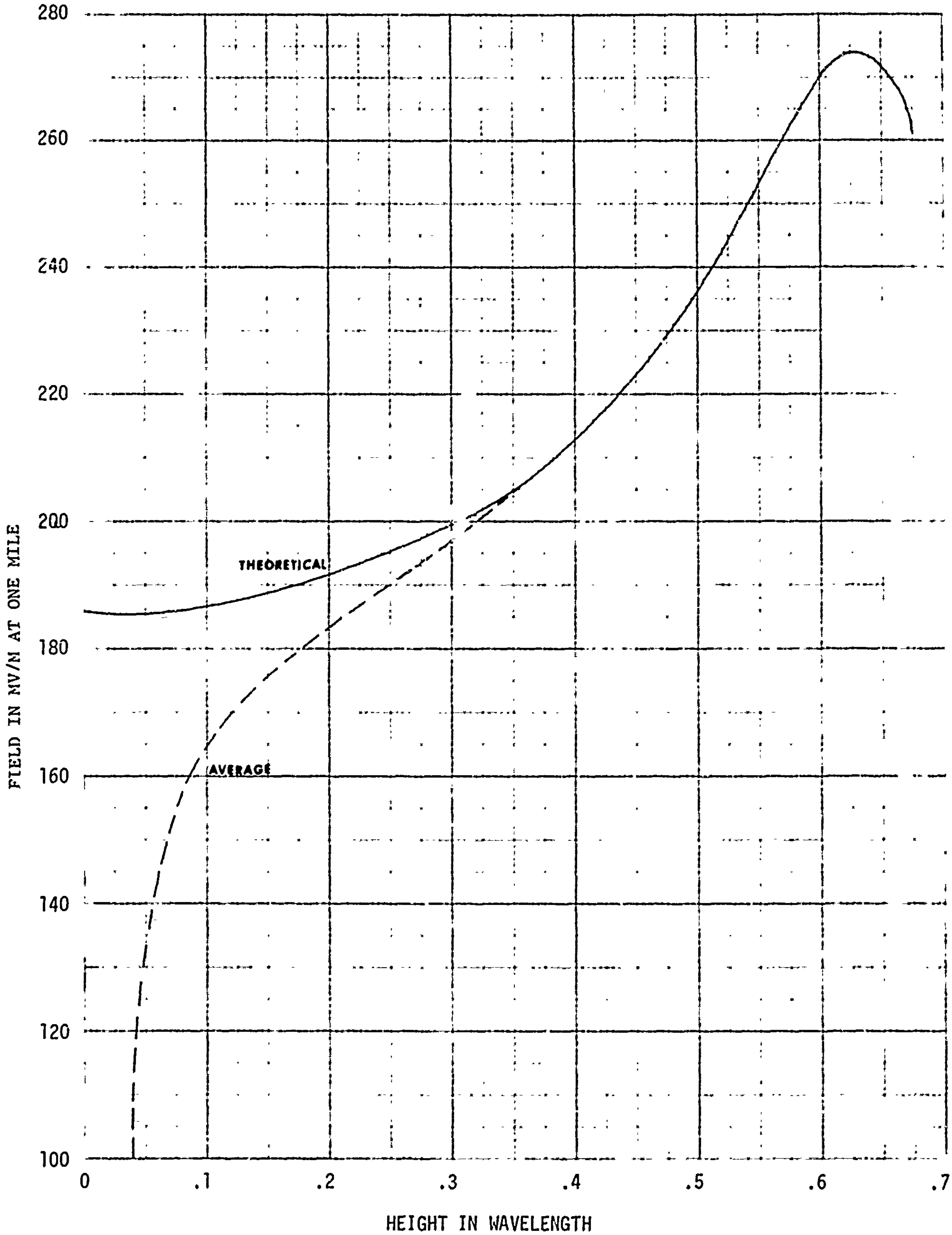


FIGURE 3.6
MONOPOLE RADIATION VS ANTENNA HEIGHT

input voltage. As an expedient antenna the very short vertical monopole with low resistance and high reactance would probably exceed in difficulty the capability of the station technician to achieve an appropriate transmitter-antenna match.

3.1.4.2 NON-VERTICAL MONOPOLE ANTENNAS

If a monopole antenna is oriented other than vertically above the ground system the characteristics are changed. Common types of non-vertical antennas are the slant wire, horizontal wire, inverted "L", and bent wire. While these are slightly different in configuration, performance characteristics are essentially identical. The names derive from the initial uses of the antenna systems.

Any monopole antenna can be characterized by its total length and average slope. When the slope is 90° the antenna is a vertical monopole and when the slope approaches 0° it is a horizontal wire antenna.

The impedance of a sloping antenna is only slightly changed from a vertical antenna even when the slope is only a few degrees. The theoretical radiation resistance and reactance of an antenna sloping only 5° above the horizontal are shown on Figures 3.7 and 3.8 respectively. As can be seen the resistance is essentially identical to the vertical antenna and the reactance is only slightly different.

The radiation pattern changes radically with the slope. For a horizontal wire radiation approaches zero off the ends of the antenna. As the slope increases, these minima fill and the pattern becomes non-directional when the slope equals 90°.

A horizontal antenna at the surface of the perfectly conducting earth will radiate no energy in the horizontal plane. Figure 3.9 shows

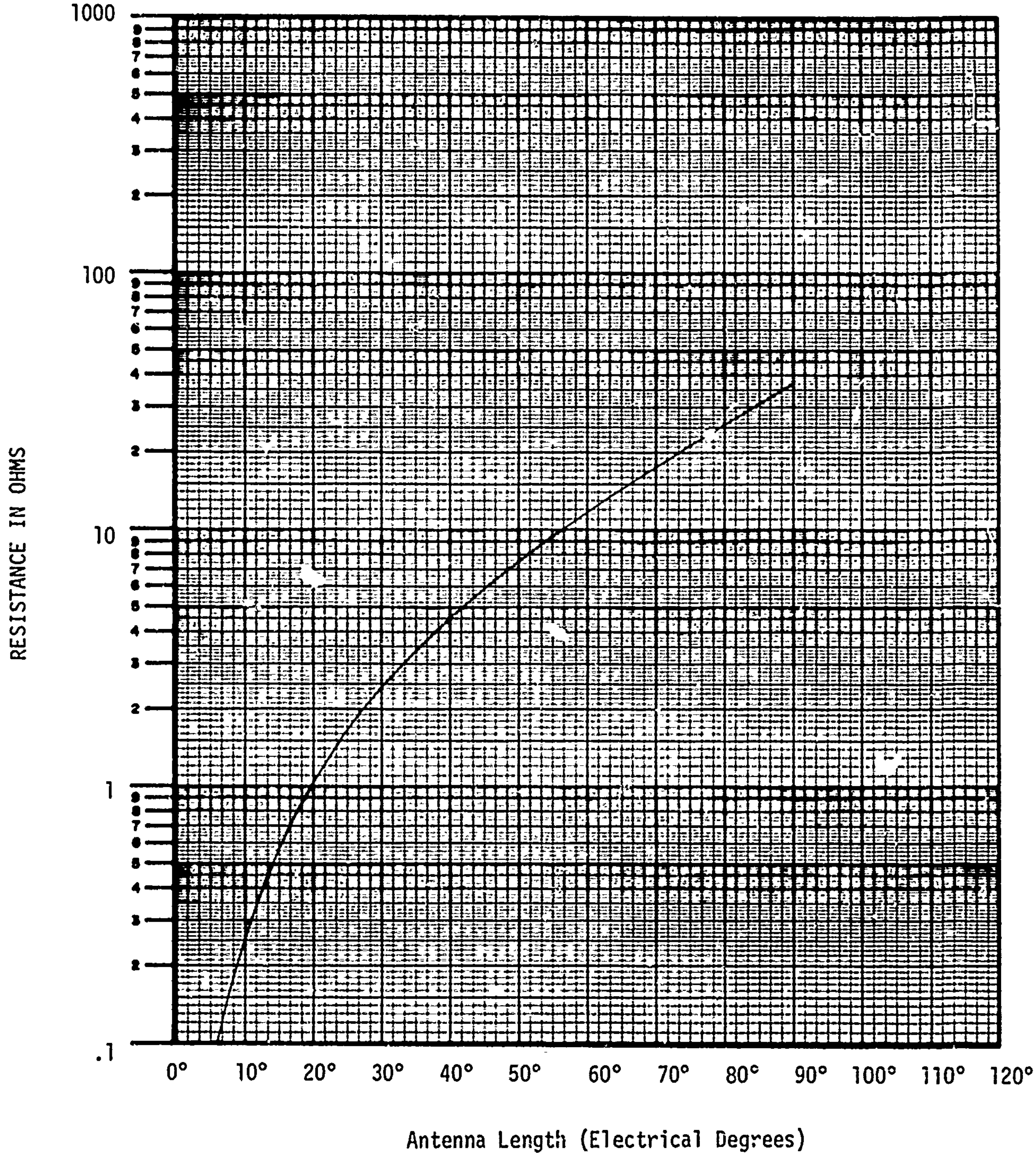


FIGURE 3.7

RADIATION RESISTANCE SLANT WIRE 5°

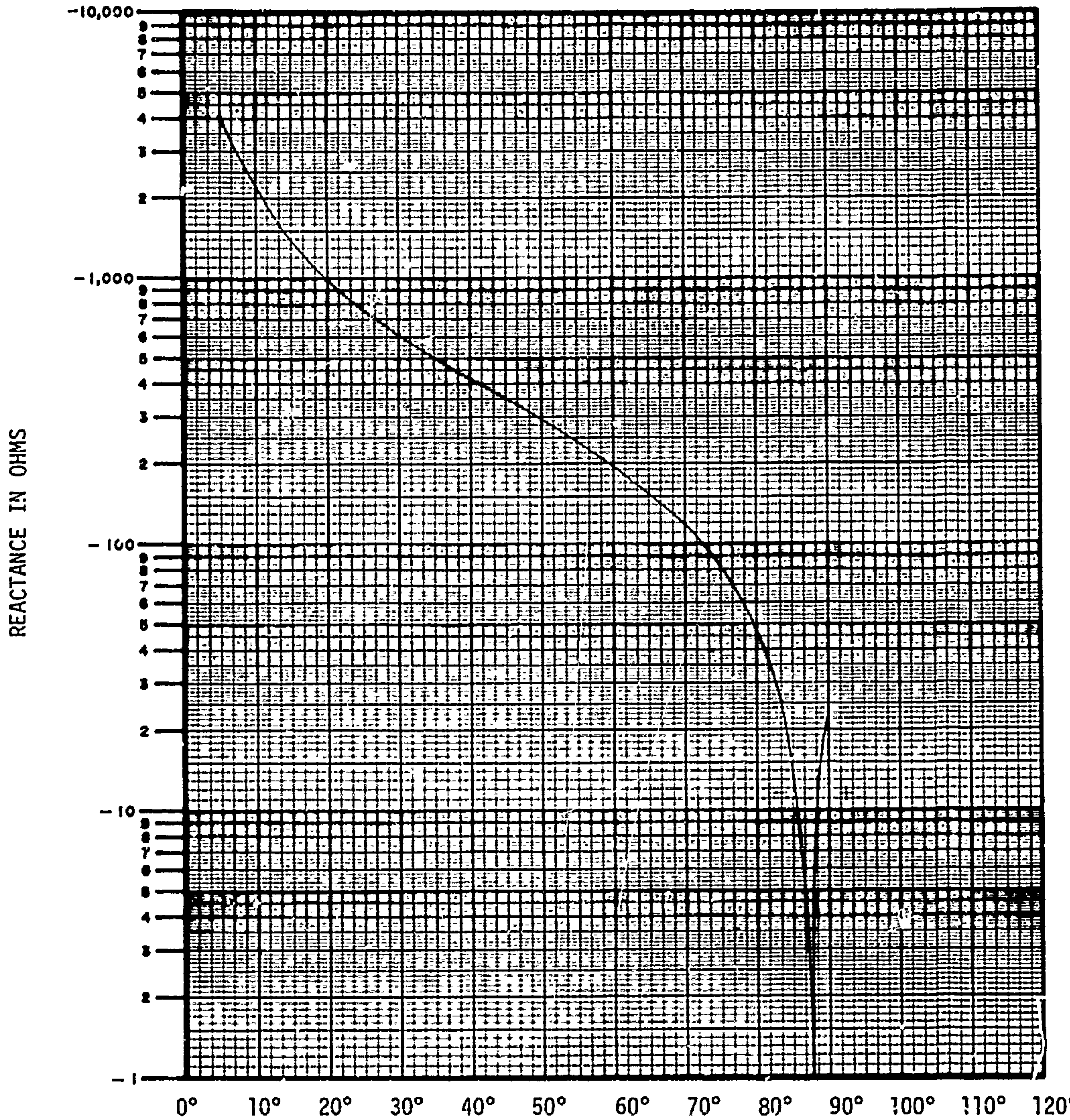


FIGURE 3.8

RADIATION REACTANCE SLANT WIRE 5°

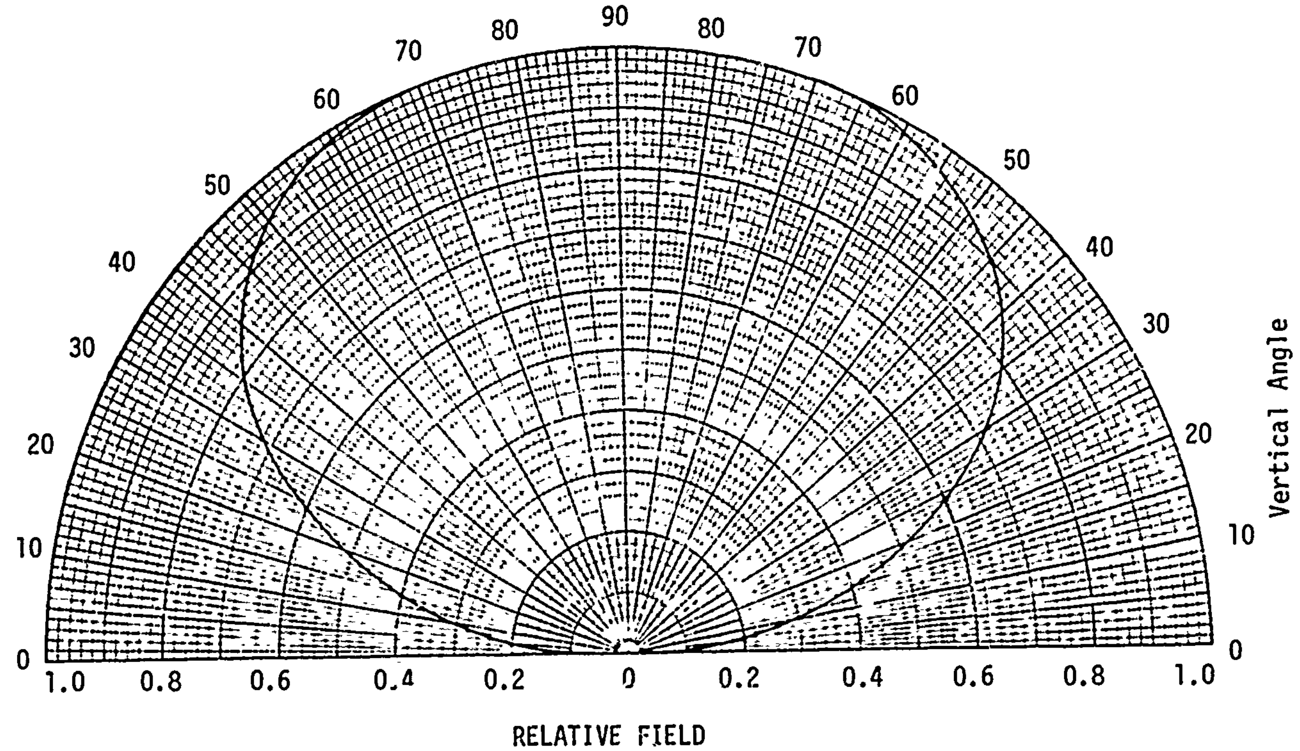


FIGURE 3.9

VERTICAL RADIATION PATTERN
HORIZONTAL WIRE ANTENNA

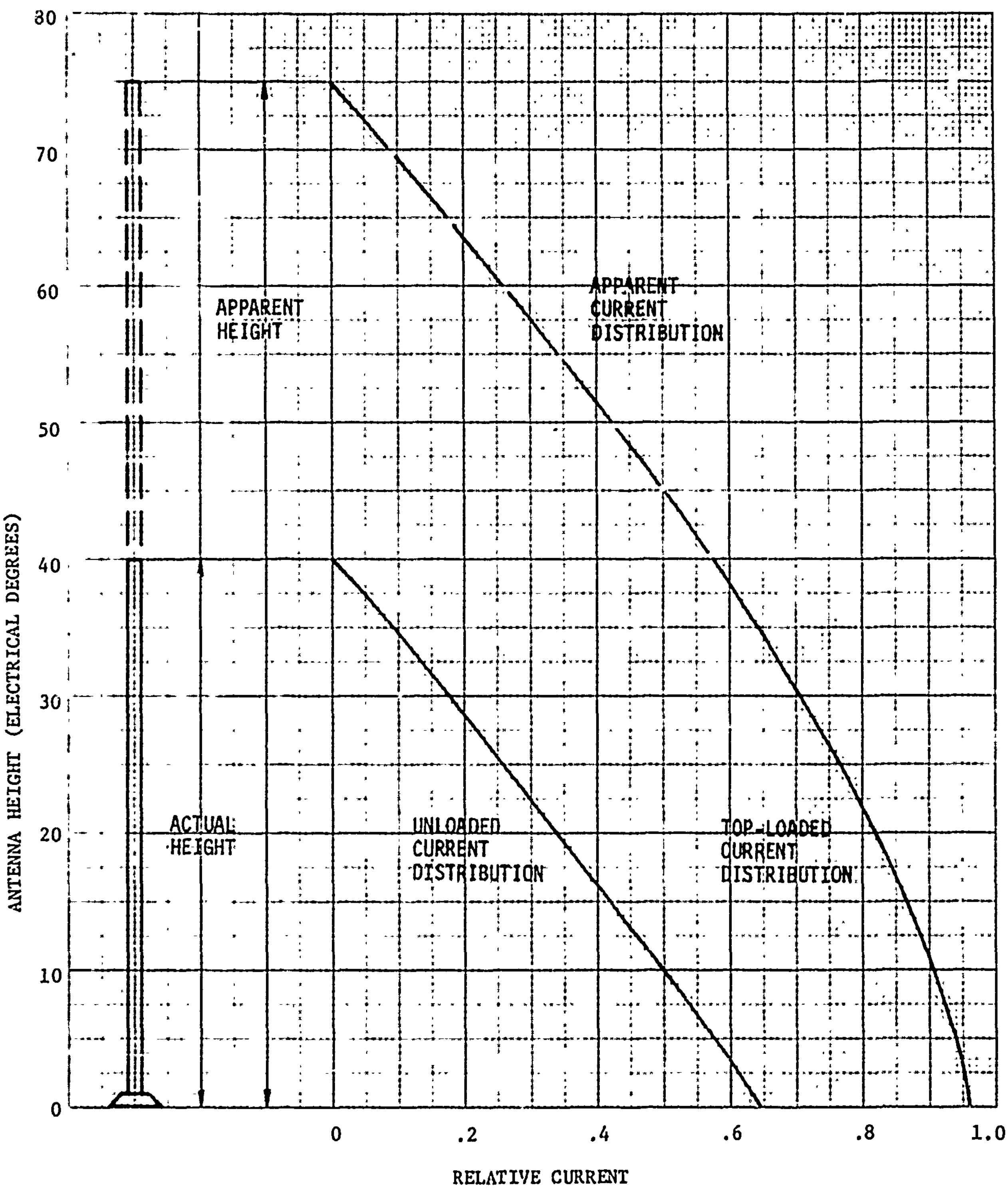


FIGURE 3.10

CURRENT DISTRIBUTION ON TOP-LOADED ANTENNA

the theoretical vertical radiation pattern of a horizontal wire on the surface of a perfect conductor. Since the earth is not a perfect conductor there will be some radiation broadside to the antenna. As the height of the antenna above ground or the slope is increased, the radiation in the horizontal plane increases and the vertical pattern approaches the vertical monopole pattern as the slope approaches 90°.

An antenna with a near horizontal slope is a very ineffective radiator for local reception. However, it is one of the easiest to deploy and use to provide limited temporary coverage.

3.1.4.3 TOP-LOADED ANTENNAS

The current distribution of a short antenna can be modified by adding capacitance to the free end. The modified current distribution approximates the sinusoidal distribution of a taller radiator. Figure 3.10 is a sketch of a top-loaded antenna showing the current distribution.

Since the current distribution determines the antenna impedance, the input impedance of a top-loaded antenna is approximately equal to the impedance of an unloaded antenna with a physical length equal to the apparent length of the top-loaded antenna. In the horizontal plane the radiation pattern is essentially identical to the pattern of an unloaded antenna. Due to radiation from the top-load, the vertical pattern may be different.

Many configurations have been developed to create the top-loading capacitance. Some of the types are: flat-top, top-hat, "T", spiral, skirt, and umbrella. Construction difficulties preclude the use of all except the "T" and umbrella as expedient antennas. The umbrella is both more effective and easier to deploy than the "T" antenna.

A sketch of a top-loaded antenna using three umbrella wires is shown on Figure 3.11. The apparent antenna length is approximately equal to the vertical length plus the umbrella length. If the umbrella length is greater than about one half the vertical height, the apparent antenna length is less than the sum of the height and the umbrella length. The apparent length can be increased slightly by adding more umbrella wires, symmetrically around the vertical radiator.

As the length of the umbrella wires is increased the vertical radiation increases. This reduces the horizontal radiation, however, the reduction is offset by an increase in efficiency due to higher input resistance. The optimum length for the umbrella appears to be approximately the height of the vertical radiator.

3.1.4.4 FOLDED UNIPOLE ANTENNA

A folded unipole antenna consists of two or more closely spaced parallel conductors. The upper ends of the conductors are connected. One conductor is used as an input and the other is grounded, sometimes through a reactance. A sketch of a folded unipole is shown on Figure 3.12.

The unipole configuration acts as a transformer and can be used to increase the input impedance. The transformation ratio is a function of the configuration and the reactance X_G.

The most common folded unipole configuration is equal diameter conductors one quarter wavelength long. The reactance X_G is not used and the transformation increases the input resistance by a factor of 4. Since the reactance of a resonant quarter wavelength antenna is zero the input reactance is zero.

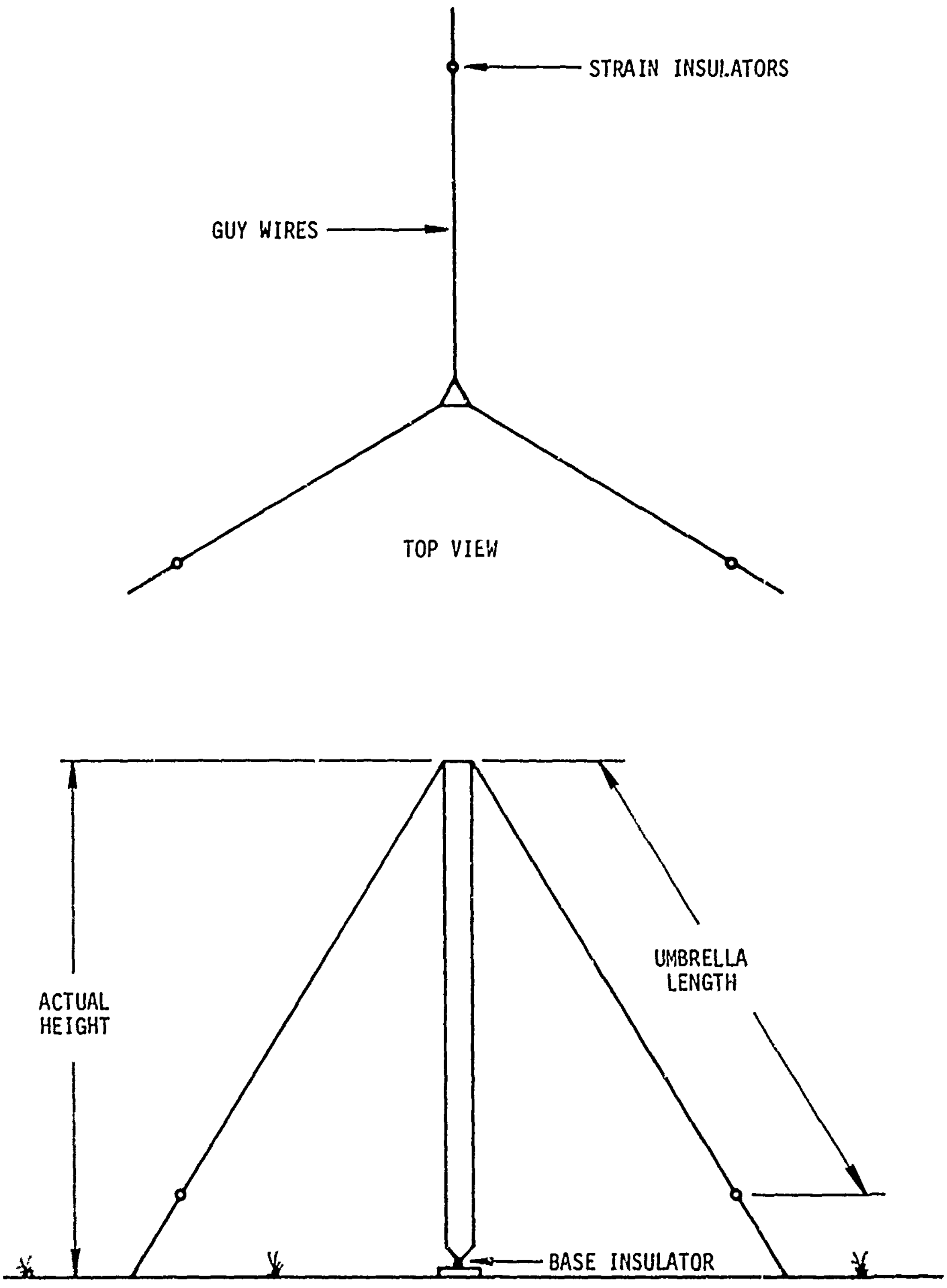


FIGURE 3.11

UMBRELLA-TYPE TOP-LOADING ANTENNA

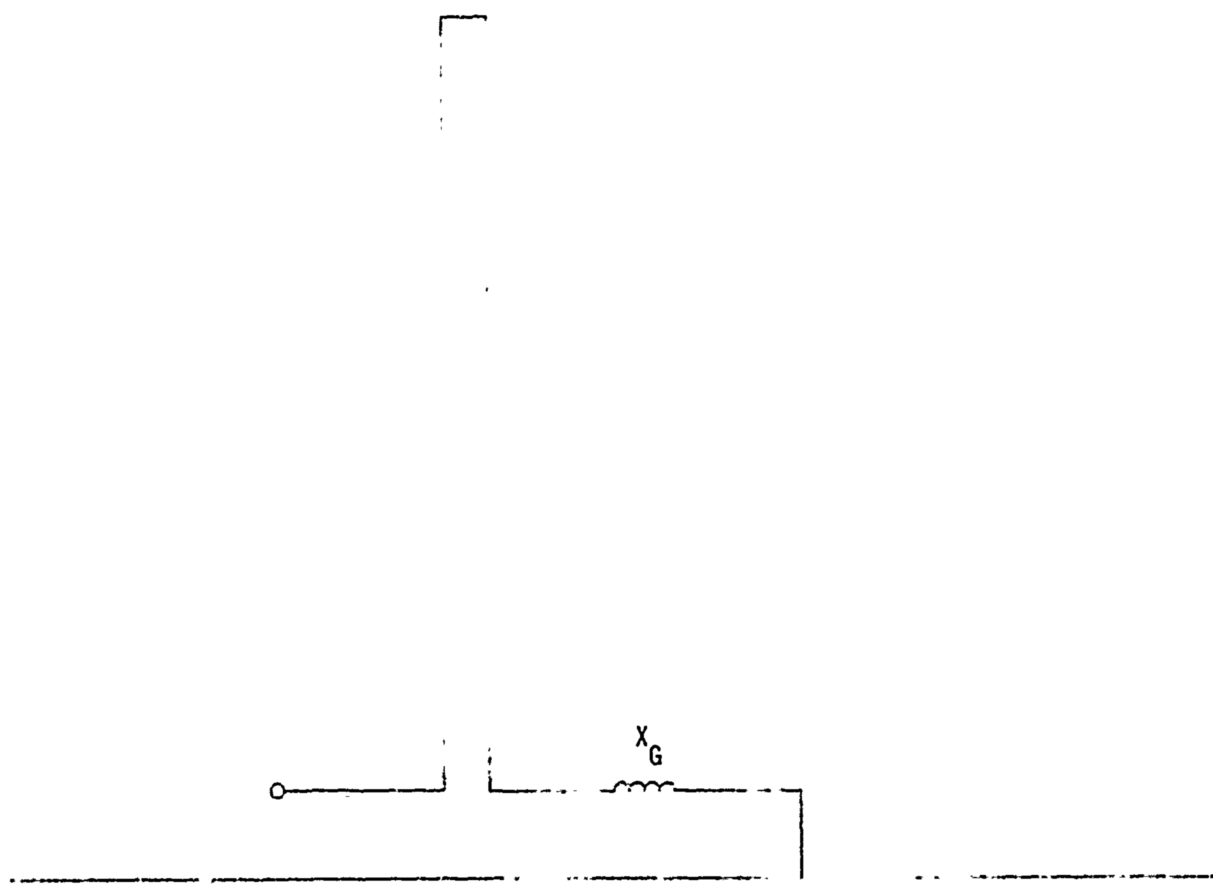


FIGURE 3.12

FOLDED UNIPOLE ANTENNA

For a short antenna the transformation is complex. For heights less than about 50° it is necessary to use the reactance X_G to increase the input resistance. By controlling the value of X_G it is possible to achieve any input resistance up to several thousand ohms.

The radiation pattern of a folded unipole is essentially identical to the pattern of a short monopole. If X_G is adjusted to produce a high input resistance the efficiency can be very high.

The adjustment of X_G is critical. Successful adjustment requires the use of an impedance bridge. Since most stations do not have an impedance bridge, it would probably not be possible to deploy the folded unipole as an expedient antenna in most situations.

3.2 PHYSICAL PROPERTIES

Any antenna system is a conducting physical structure. The ability to rapidly fabricate or deploy the physical structure necessary for an antenna system limits the types of feasible expedient antennas.

A rigid steel tower is used as an antenna by essentially all radio stations. The tower may be either guyed or self-supporting. Top-loaded antennas normally use a rigid tower as the principal radiator and umbrella wires for the top-loading. It is not possible for a technician to erect an equivalent tower for an expedient antenna under emergency conditions.

The easiest and fastest expedient antenna to deploy is the horizontal or slant wire. The antenna properly insulated can be supported by posts, trees, buildings, or any other natural or man-made structure. The higher the antenna is supported above ground the more effective it will be.

If a wire is to be used as an antenna, consideration must be given to current carrying capacity. A #10 gauge wire is rated at 35 amperes

Thus, for a power of 1000 watts, the antenna input resistance must be greater than 1 ohm. For 10,000 watts the resistance must be at least 10 ohms. These minimum resistances correspond to minimum lengths of about 20° and 60° for 1000 watts and 10,000 watts respectively. For shorter antenna lengths, larger wire must be used.

One method of achieving a vertical antenna is to suspend a wire from a balloon. The wire length can be cut to one quarter wavelength or greater if desired. However, if a 10 foot diameter helium filled balloon is used the maximum weight must be less than 23 pounds. Copper wire, size #10, weighs about 31 pounds per thousand feet. Thus a quarter wavelength antenna at 540 kHz would weigh about 15 pounds.

The 10 foot balloon would support the antenna under zero wind velocity conditions. With a 30 mph wind, drag on the balloon would be 140 pounds and the average slope of the wire would be less than 10°. In slightly gusting wind, portions of the antenna would probably contact the ground and short out the antenna. At least a 50 foot diameter balloon would be required to have a reasonable assurance of maintaining a usable antenna. An additional tether cable would be required to anchor the balloon since the tensile strength of #10 copper wire is only about 540 pounds. Even ignoring the problems of storing the balloon and helium it is doubtful that one man could deploy a 50 foot balloon.

Light weight towers such as are used to support television receiving antennas can be erected in a few hours by two men. The maximum height is about 70 feet. If such a tower were top-loaded, it could form a useable antenna system for frequencies above 1200 kHz.

A number of quick erect towers have been developed, and one of these, a lattice tower, is shown on Figure 3.13. According to the manufacturer, two men can erect a 100 foot tower in about one hour. However, the cost of about $7,000 for 100 feet may be prohibitive in the DCPA application. A height of at least 150 feet would be required for a top-loaded tower at 540 kHz.

3.3 RECOMMENDATIONS

Time is probably the most important consideration in restoring communications, and the expedient antenna to be deployed should be as simple as possible in order to save construction time.

Approximately 25 percent of AM broadcasting stations use a directional antenna system consisting of two or more towers. If there is a surviving tower, then this tower is recommended for use as an expedient antenna. If there are no surviving towers, the antenna fastest to deploy is the horizontal wire. Unfortunately, it is also the least effective. A top-loaded vertical antenna has reasonable effectiveness but requires substantial time to deploy. A two step deployment is therefore the recommended strategy. A horizontal wire should be deployed for immediate limited service and, (while using the horizontal wire in the interim), a top-loaded antenna should be constructed at key stations. This should permit restoration of limited communications within 30 minutes and effective communications at critical points within 8 hours.

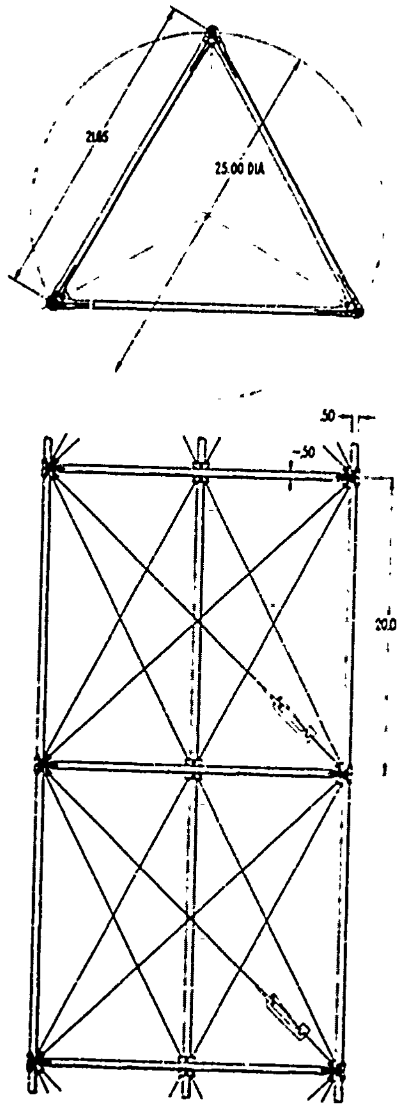


FIGURE 3.13

LATTICE TOWER

IV. AM FEEDER SYSTEMS

4.0 GENERAL

Most antenna systems require an impedance matching network to couple from the transmission line to the antenna. The network usually consists of lumped inductance and capacitance in the form of L, T. or π sections. If the antenna input is not a pure resistance, it can be made to look like a pure resistance by adding a reactance element in series that will make the antenna series resonant. This is usually done to simplify the network design.

The antenna input impedance is:

$Za = Ra + jXa$

where Ra is the resistive component

Xa is the reactive component

If a series reactance (Xs) is added such that $Xs = -Xa$ the input is resonant and the coupling problem reduces to matching a pure resistance (Zo, the transmission line impedance) to a pure resistance (Ra).

4.1 L SECTIONS

An L section consisting of an inductor and a capacitor is the simplest match between pure resistances. Figure 4.1 is a sketch of a basic L section. The larger terminating resistance is designated as R_1 and the transformation ratio is defined as $r = R_1/R_2$

For most expedient antennas the characteristic impedance (Zo) of the transmission line will be greater than the antenna input resistance (Ra). Thus, R_1 can be identified as Zo and R_2 as Ra. In the case of a tall or long antenna where Ra is greater than Zo the relationship is reversed.

The design equations for an L section are:

$$Z_2 = \pm j\ R_2 \sqrt{r-1} = \pm j\ R_1/a$$

$$Z_3 = \mp j\ R_1/\sqrt{r-1} = \pm j\ R_1/b$$

where Z_2 is the series reactance

Z_3 is the shunt reactance

$a = r/\sqrt{r-1}$

$b = \sqrt{r-1}$

The $\pm j$ in the equation for Z_2 and the $\mp j$ in Z_3 means simply that if $+j$ or an inductor is selected for Z_2 then $-j$ or a capacitor must be used for Z_3. The reverse is also permissible. The values of a and b as a function of r are shown on Figure 4.2.

When the series arm of the network occurs on the antenna side, Z_2 may be combined with Xs as shown on Figure 4.3.

The reactance of inductors and capacitors are a function of frequency and is given by:

$$X_L = 2\pi fL$$

$$X_C = 1/2\pi fC$$

where X_L is the inductive reactance

X_C is the capacitive reactance

f is the frequency in MHz

L is the inductance in microhenrys

C is the capacitance in microfarads

4.2 T AND π SECTIONS

With three reactive elements the adjustment of the network is simplified. It is also possible to control the phase shift as well as

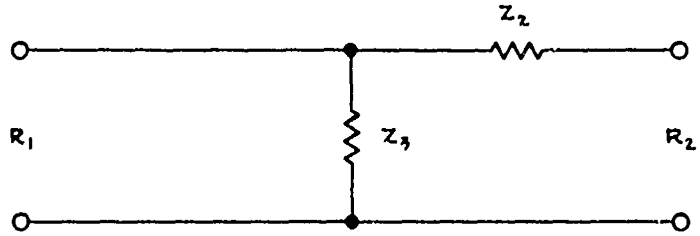


FIGURE 4.1
GENERAL L-SECTION
IMPEDANCE-MATCHING NETWORK

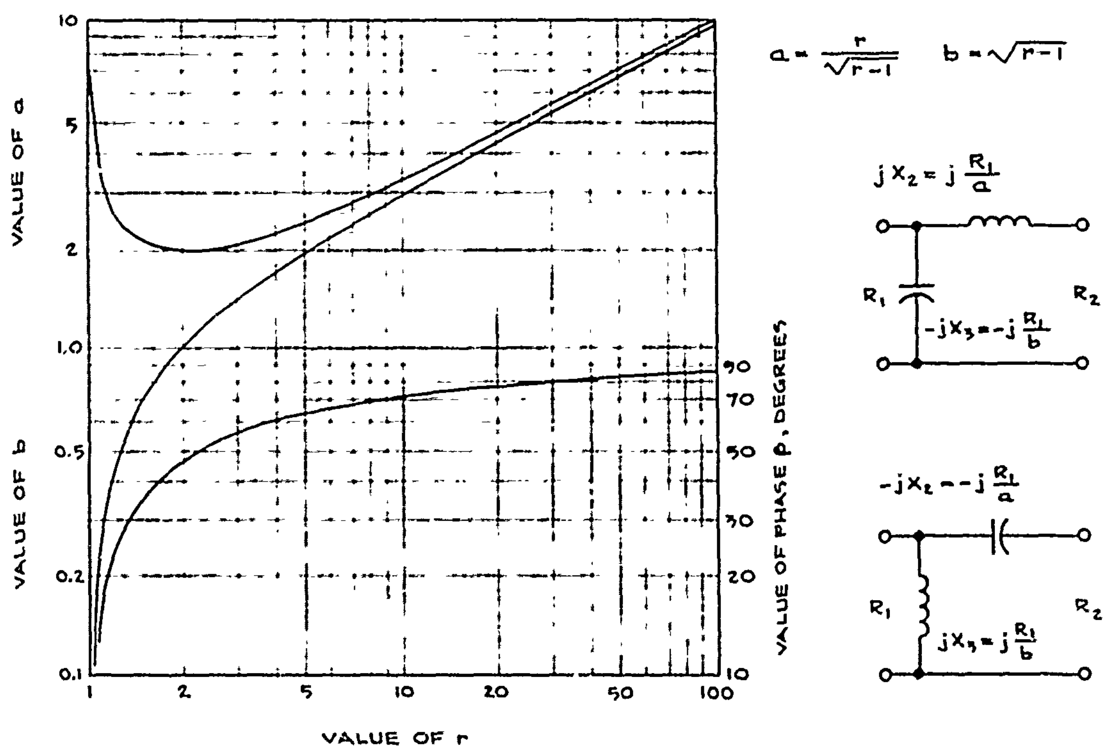


FIGURE 4.2
L-SECTION DESIGN CHART

match the impedance, however, control of the phase shift is not important for non-directional operation.

Figure 4.4 is a sketch of basic T and π sections. The design parameters for T and π sections are:

$$a = \frac{r \sin \beta}{\sqrt{r} - \cos\beta}$$

$$b = \sqrt{r} \sin \beta$$

$$c = \frac{\sqrt{r} \sin \beta}{1 - \sqrt{r} \cos \beta}$$

where r is the transformation ratio

β is the phase shift

The design equations for a T network are:

$$Z_1 = j R_1/c$$

$$Z_2 = j R_1/a$$

$$Z_3 = j R_1/b$$

The design equations for a π network are:

$$Za = j aR_2$$

$$Zb = j bR_2$$

$$Zc = j cR_2$$

There is no basic choice between a T and π except ease of adjustment. A T network is easier to adjust than a π or an L network.

4.3 TRANSMISSION LINES

Except in rare instances, radio stations require a transmission line between the transmitter and the antenna tuning netowrk. For maximum

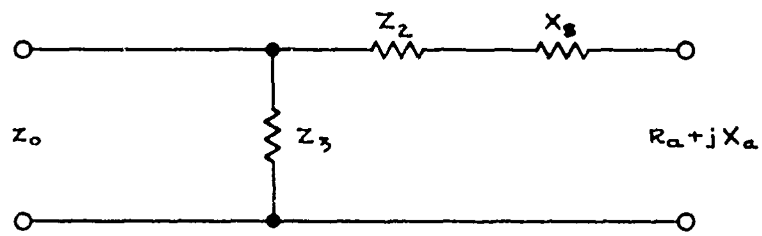
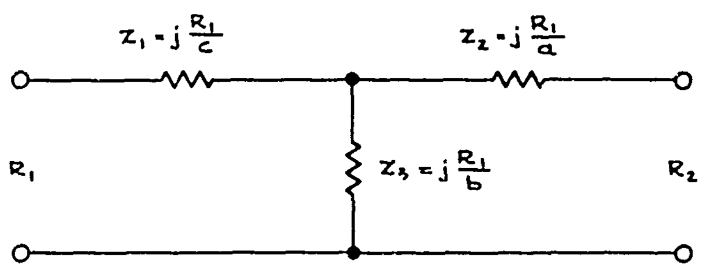
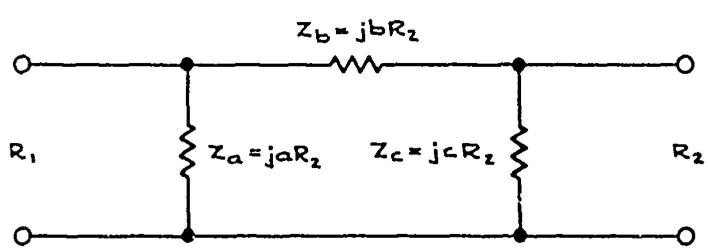


FIGURE 4.3
L - SECTION SHOWING
RESONATING REACTANCE, X_s



(a) T - SECTION



(b) π - SECTION

FIGURE 4.4
GENERAL T- & π - SECTION
IMPEDANCE - MATCHING NETWORK

efficiency in transfer of energy the transmission line must be terminated by a load equal to its characteristic impedance.

In general the characteristic impedance is a pure resistance

$$Zo = L/C$$

where L is the inductance per unit length

C is the capacitance per unit length

For a simple coaxial line the characteristic impedance is:

$$Zo = \frac{138}{\epsilon} \log \frac{D}{d}$$

Where ϵ is the dielectric constant

D is the inside diameter of the outer conductor

d is the outside diameter of the inner conductor

For a parallel two-wire transmission line the characteristic impedance is:

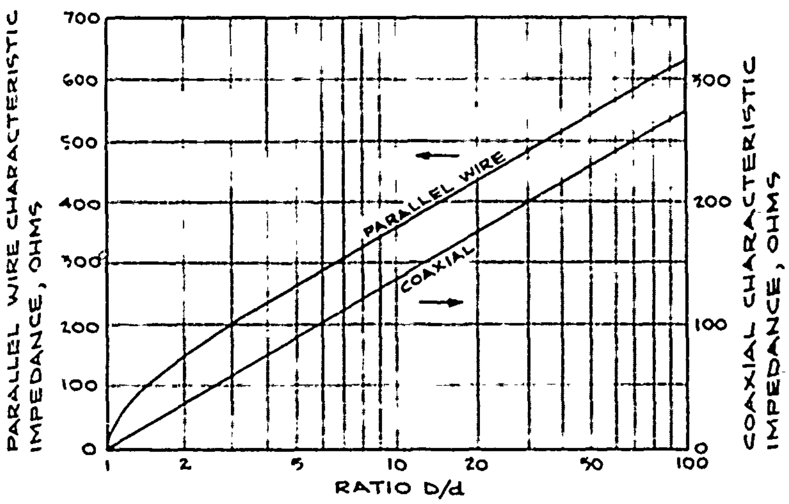
$$Zo = 120 \cosh^{-1} \frac{D}{d}$$

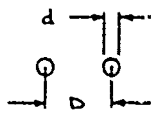
Where D is the spacing between conductors centers

d is the diameter of conductors

The characteristic impedance of coaxial and two-wire transmission lines is shown on Figure 4.5.

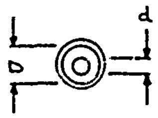
It is possible to construct an expedient transmission line under emergency conditions, however, this should be the last resort. If a transmission line, even of the wrong characteristic impedance, is available it should be used. The mismatch and power loss will probably be considerable less than would occur with an improvised line.





$$Z_0 = 120 \cosh^{-1} \frac{D}{d}$$

PARALLEL WIRES IN AIR



$$Z_0 = \frac{138}{\sqrt{\epsilon}} \log_{10} \frac{D}{d}$$

SINGLE COAXIAL LINE FOR $\epsilon = 1$

FIGURE 4.5
CHARACTERISTIC IMPEDANCE OF COAXIAL AND TWO-WIRE TRANSMISSION LINES.

V. EVALUATION OF FM ANTENNAS

5.0 GENERAL

The basic theory of antennas applies to FM as well as AM. However, the smaller physical dimensions present entirely different design considerations. One wavelength at FM frequencies is about ten feet. An FM antenna does not utilize a ground system, and most are modifications of a balanced dipole. Frequently FM antennas are stacked vertically to provide power gain in the horizontal plane, and each element in the stack is referred to as a bay. A four-bay antenna with an input power of 1 KW has an effective radiated power of approximately 4 KW. Primary FM radiation is horizontally polarized. A vertically polarized component is permissible but not required under the FCC rules. The supporting tower is not an integral part of the FM antenna but the metal structure near the antenna can distort the radiation pattern and the input impedance. For this reason, FM antennas must be designed to operate on specific types of towers to achieve acceptable patterns and input impedances.

5.1 SIMPLE DIPOLE ANTENNA

The radiation from a simple dipole is polarized in the plane of the dipole. The radiation pattern is shown in Figure 5.1.

If the dipole is oriented vertically, a non-directional pattern with vertical polarization is produced. If the dipole is oriented horizontally, a figure-eight pattern with horizontal polarization is produced. Thus, the simple dipole is an excellent antenna for vertical polarization but a poor antenna for horizontal polarization.

5.2 "V" ANTENNA

The "V" antenna (Figure 5.2) is essentially a bent horizontal dipole. A symmetrical "V" antenna will yield a figure-eight horizontal pattern. The pattern can be made to approach non-directional by unbalancing the current and phasing in the two elements.

5.3 RING ANTENNA

The basic radiating element of a ring antenna (Figure 5.3) is an end-loaded half-wave dipole. The dipole is bent into a loop so that the end-loading discs form a capacitor.

5.4 RECOMMENDATIONS

The design of FM antennas has been developed to a precise art and it is not practical to design an expedient antenna competitive with antennas commercially available.

It is recommended that a one or two bay, horizontally polarized, ring antenna be used as an expedient antenna. The antenna should be mounted on a 30 foot pole.

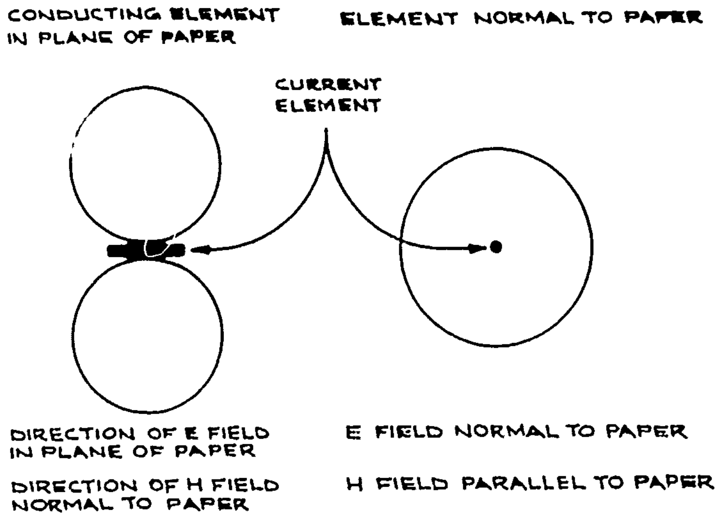


FIGURE 5.1
RADIATION PATTERNS THROUGH
℄ NORMAL TO CURRENT ELEMENT

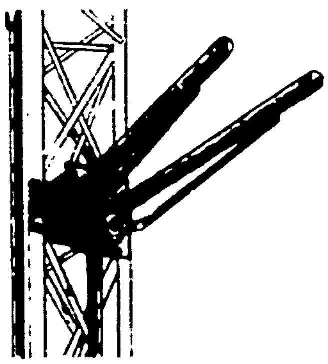


FIGURE 5.2
SINGLE RADIATING
ELEMENT OF "V"
FM ANTENNA

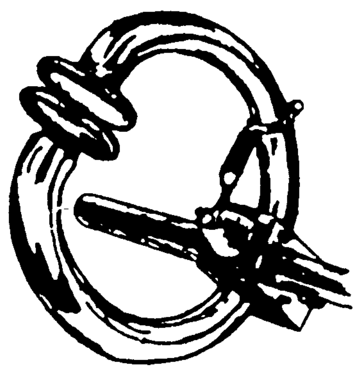


FIGURE 5.3
SINGLE RADIATING
ELEMENT OF RING
FM ANTENNA

VI. SUMMARY AND RECOMMENDATIONS

6.0 SUMMARY

An expedient antenna may be deployed following the destruction of the normal antenna to provide emergency information dissemination. It is assumed that the normal antenna would be destroyed during severe environmental disturbances and that the station personnel would have not received a warning during the imminent phase. Under these assumed conditions, non-technical personnel (announcer, etc.) should be ready to disseminate emergency information in about 30 minutes. The technician if not already on duty will probably arrive at the transmitter in approximately 30 minutes. Thus, the station personnel are ready to broadcast emergency information at about the time the technician becomes available to deploy an expedient antenna.

Assumed loss as the result of delay in transmission of emergency information rises sharply at about one hour. For this reason a deployment time goal has been set at 30 minutes after arrival of the technician at the transmitter.

Should one or more towers of the regular antenna system remain intact one of these towers should be used as a non-directional expedient antenna. The time required to return to service using an existing tower should not exceed 15 minutes.

If all towers are destroyed, an elevated horizontal wire antenna should be deployed. (The detail design and performance characteristics of an elevated horizontal wire antenna are presented in Appendix A.

Procurement specifications for various frequencies and power levels are presented in Appendix B.) If supporting poles have been installed in advance it should be possible for one technician to deploy the packaged horizontal wire antenna in less than 30 minutes.

As shown in the detail design, the horizontal wire antenna is very inefficient, however, it should be a satisfactory expedient antenna for most stations. In the relatively few cases where the horizontal wire is inadequate, it may be desirable to deploy a top-loaded antenna. Due to the time required to deploy a top-loaded antenna, however, the horizontal wire antenna should be deployed to provide interim partial service. Estimated time required for two technicians to deploy a top-loaded antenna ranges from 8 hours for 1600 kHz to over 24 hours for 540 kHz.

The best expedient for FM is a one or two bay commercial antenna. The antenna would be mounted on a thirty foot pole. Procurement specifications for one and two bay antennas are contained in Appendix C.

A horizontal wire expedient antenna package to be supplied to all AM stations in the Radio Broadcast Station Protection Program has been designed. For selected stations a top-loaded antenna package may be desirable.

As a minimum assistance to stations not in the Radio Broadcast Station Protection Program, procedures for the construction of an expedient antenna from available materials have been devised. Appendix D is a monograph covering techniques for construction of these expedient antennas.

6.1 RECOMMENDATIONS

1. Distribute one copy of the expedient antenna construction monograph to all AM broadcasting stations.

2. Supply a horizontal wire expedient antenna package, appropriate for the station's frequency and power, to each AM station in the Radio Broadcast Station Protection Program.

3. For selected stations in major metropolitan areas, supply a top-loaded expedient antenna using a quick-erect tower custom designed for each installation.

4. Supply an expedient FM antenna package to each FM station in the Radio Broadcast Station Protection Program.

5. As a follow-on to this present work, fabricate and field test sufficient prototype expedient antennas to confirm the concept and verify installation procedures and operational effectiveness of the proposed packages.

GLOSSARY

1. AM BROADCASTING STATION - A commercial or educational station utilizing amplitude modulation (AM) and operating in the 540 kHz - 1600 kHz portion of the electro-magnetic spectrum.

2. ANTENNA EFFICIENCY - Percent transmitter power actually radiated by the antenna.

3. ANTENNA SYSTEM - Radiating element(s) and associated ground radials, matching networks and transmission line.

4. COVERAGE AREA - Geographical area in the vicinity of a broadcast station encompassed within the signal level iso-intensity contour representing minimum usable signal.

5. DIRECTIONAL ANTENNA SYSTEM - An antenna system designed to suppress radiation in some directions and enhance it in others. Utilized by some AM broadcasting stations to protect other stations from interference. Rarely utilized to beam power in directions where greater coverage is desired.

6. EXPEDIENT ANTENNA - An emergency replacement for use in case of loss of, or catastrophic damage to, the normal antenna system.

7. FM BROADCASTING STATION - A commercial or educational station utilizing frequency Modulation (FM) and operating in the 88 MHz to 108 MHz portion of the electromagnetic spectrum.

8. Hz - Abbreviation for hertz, unit of frequency equal to one cycle per second.

9. IMPEDANCE - Combination of resistive and reactive opposition to flow of alternating current in an electrical circuit.

10. kHz - Abbreviation for kilohertz

11. MHz - Abbreviation for megahertz

12. MV/M - Abbreviation for millivolts per meter, unit of signal strength defined as that signal strength which will induce a potential of one millivolt across one meter of wire.

13. RADIATED POWER - Energy actually radiated by the antenna as electro-magnetic waves, equal to transmitter power output minus system losses.

14. RADIATION PATTERN - Distribution of radiated signal horizontally about the antenna and in the space above the horizon.

15. RADIATOR - That element in an antenna system which radiates electro-magnetic energy.

16. RADIO PROPAGATION - Extension of electro-magnetic signal from the transmitting source outward through the coverage area. Propagation is affected by radiated power, inverse distance and propagation path losses.

17. SOIL CONDUCTIVITY - The quality of soil as it affects ground wave propagation of electro-magnetic waves.

18. TRANSMISSION LINE - Multi-element conductor usually co-axial cable utilized by broadcasting stations to connect transmitter and antenna.

19. TRANSMITTER - Device utilized to generate and modulate electro-magnetic energy of appropriate frequency and power for broadcast use.

20. TRANSMITTER EFFICIENCY - Ratio of input electric power to transmitter output power expressed in percent.

21. TRANSMITTER POWER - Transmitter power output usually expressed in watts.

22. UNATTENUATED INVERSE FIELD - A reference field intensity expressed in MV/M at one mile, related to radiated power and the radiation pattern.

23. WAVELENGTH - The length of one complete electro-magnetic wave or cycle. Wavelength is frequency dependent.

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APPENDIX A

DETAILED DESIGN OF HORIZONTAL WIRE ANTENNA

A.0 GENERAL

A horizontal wire antenna consists of an insulated wire above a ground system. The feed point of the antenna is near the center of the ground system. Figure A.1 is a sketch of the horizontal wire antenna proposed for use as an expedient antenna system.

A.1 PHYSICAL DIMENSIONS

The total conducting length was selected to be 0.2375 wavelengths or 85.5 electrical degrees. Nominal antenna input impedance for this length is 35 + j0 ohms. The physical length of the conductor is a function of frequency:

$$\text{Length} = 234{,}000/f$$

where f is the frequency in kHz

The principal part of the antenna is supported by insulators on two 30 foot wood poles. The distance between the poles is a function of frequency and is 80 feet less than the wire length. The conductor is #10 copper clad braided wire.

A.2 INPUT IMPEDANCE

Theoretical antenna input impedance is 35 + j0 ohms. Actual impedance may vary substantially. For design purposes it is assumed that the actual input impedance may be any value within the range of $20 \pm j100$ ohms to $48 \pm j75$ ohms.

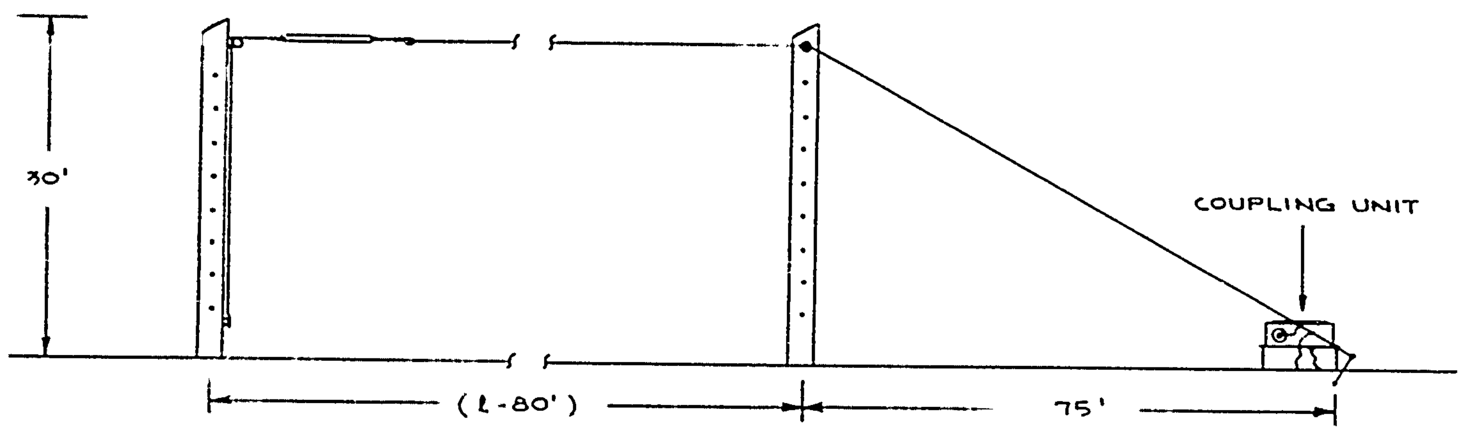


FIGURE A.1

SKETCH OF HORIZONTAL WIRE ANTENNA

A.3 INPUT CURRENT AND VOLTAGE

The input current (Ia) is a function of the input power (P) and antenna resistance (Ra):

$$Ia = \sqrt{P/Ra}$$

The input voltage is a function of the current and the input impedance (Za):

$$Va = IaZa$$

With modulation the current increases by a factor of 1.225 and the voltage increases by a factor of 2.

Figure A.2 is a tabulation of the nominal and maximum antenna input currents and voltages for several power levels.

A.4 MATCHING NETWORK

An L-section is proposed as a matching network. Figure A.3 is a sketch of the network.

For the nominal antenna impedance of 35 + j0 ohms the reactance of the shunt element is +j76.4 ohms and the reactance of the series element is -j22.9 ohms. To permit matching any antenna impedance in the range of 20 $\pm$ j100 ohms to 48 $\pm$ 75 ohms, the adjustment range of the shunt element is +j40 ohms to +j245 ohms and the adjustment range of the series element is -j145 ohms to +j65 ohms.

The tuning unit is enclosed in a weatherproof housing as shown in Figure A.4.

While it is possible to design a universal matching network for all frequencies, substantial reduction in cost and in size can be achieved by designing tuning units for smaller frequency ranges. The AM broadcast band

Without Modulation

Power	Input Current		RMS Input Voltage	
	Nominal	Max.	Nominal	Max.
.25 KW	2.7 amps	3.5 amps	95 volts	357 volts
1.0 KW	5.4 amps	7.1 amps	189 volts	724 volts
5.0 KW	12.0 amps	15.8 amps	420 volts	1611 volts
10.0 KW	16.9 amps	22.4 amps	592 volts	2284 volts

With Modulation

Power	Input Current		Peak Input Voltage	
	Nominal	Max.	Nominal	Max.
.25 KW	3.3 amps	4.3 amps	269 volts	1010 volts
1.0 KW	6.6 amps	8.7 amps	535 volts	2048 volts
5.0 KW	14.7 amps	19.4 amps	1188 volts	4557 volts
10.0 KW	20.7 amps	27.4 amps	1674 volts	6460 volts

Figure A.2

Antenna Input Current and Voltage

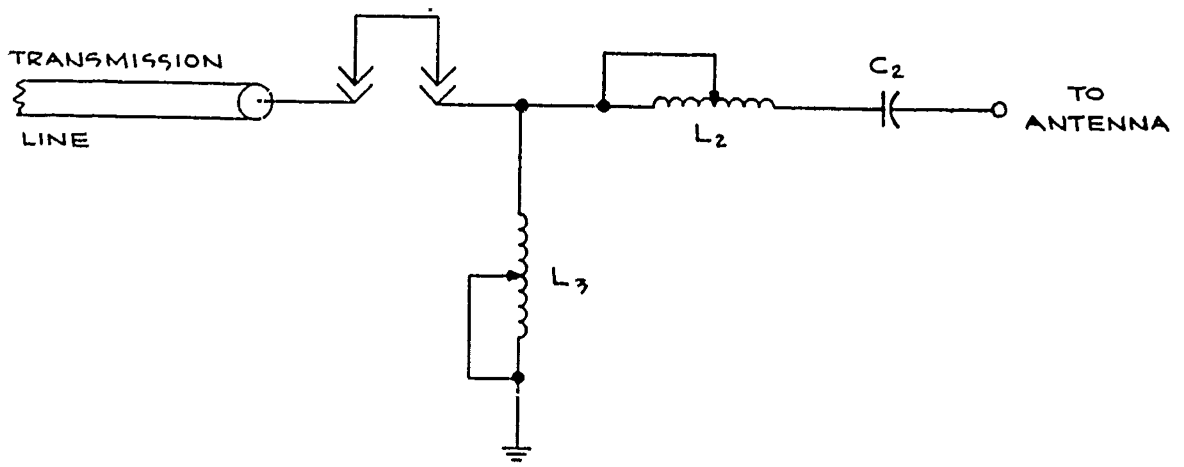


FIGURE A.3

MATCHING NETWORK

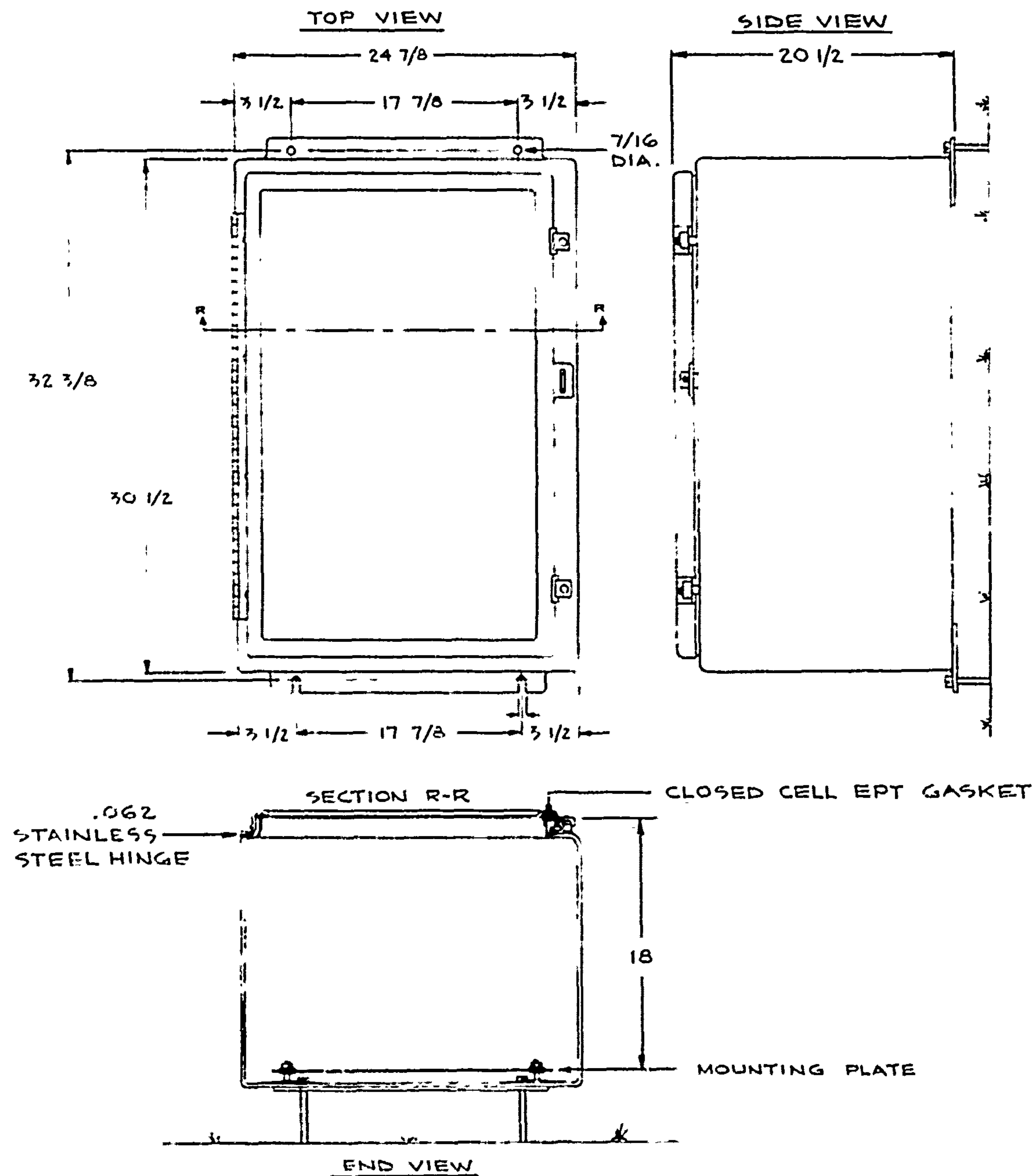


FIGURE A.4
WEATHER-PROOF HOUSING FOR
ANTENNA TUNING UNIT

has been divided into four regions for convenience; 540 to 750 kHz, 750 to 1000 kHz, 1000 to 1300 kHz, and 1300 to 1600 kHz. Matching networks have been designed for use within each of these regions.

Since the size of the components in the matching network is dependent on the power, high and low power units have been designed. A total of ten different matching networks have been designed; for each of four frequency regions plus a universal and in each case for power levels of 1 KW and 10 KW. The parts required for each of these units are tabulated in Appendix B.

A.5 RADIATION PATTERN

The radiation in the horizontal plane from an elevated horizontal wire is not readily amenable to exact mathematical analysis. By making several simplifying approximations, however, it is possible to arrive at a predicted approximate radiation pattern. Actual radiation may diverge substantially from the predicted.

The radiation pattern of a dipole in free-space is well known. Maximum radiation is perpendicular to the antenna and there are nulls off the ends. A horizontal antenna located on a perfectly conducting surface radiates no energy in the horizontal plane. The entire energy is radiated above the plane.

Neither of the above cases corresponds closely to the actual antenna, but both are conceptually useful for analysis.

One simplification is to assume that the antenna is a slant wire with a constant slope equal to the average slope of the elevated wire antenna. The horizontal radiation pattern for a slant wire antenna in free-space is given by:

$$E' = \sqrt{\sin^2\theta + (\cos\theta \sin\alpha)^2}$$

where θ is the slope angle

α is the azimuth angle.

The magnitude of the radiation is a function of the average slope of the antenna and close-in ground conductivity. For a slope of 0° the radiation in the horizontal plane is zero and for a slope of 90° the radiation is about 190 mv/m at one mile for 1 KW input power. The radiation is assumed to increase as the sine of the antenna slope. If the ground is not perfectly conducting, there is an energy loss in the image antenna which results in an unbalanced dipole radiation. The unbalance results in some radiation in the horizontal plane. None of the methods of predicting the radiation appear to correspond closely to the experimental. While experimental results have differed radically, it appears that the radiation from the elevated horizontal wire at 540 kHz will be about 40 mv/m at one mile for 1 KW. Since average slope and ground conductivity effects increase with frequency, the antenna should be more efficient at higher frequencies. The radiation is assumed to be 70 mv/m at 1000 kHz and 100 mv/m at 1600 kHz. The assumed radiation patterns for 540, 1000, and 1600 kHz are shown on Figures A.5, A.6, and A.7 respectively. Figure A.8 is a tabulation of the predicted service areas assuming ground conductivities of 2 mmho/m and 8 mmho/m.

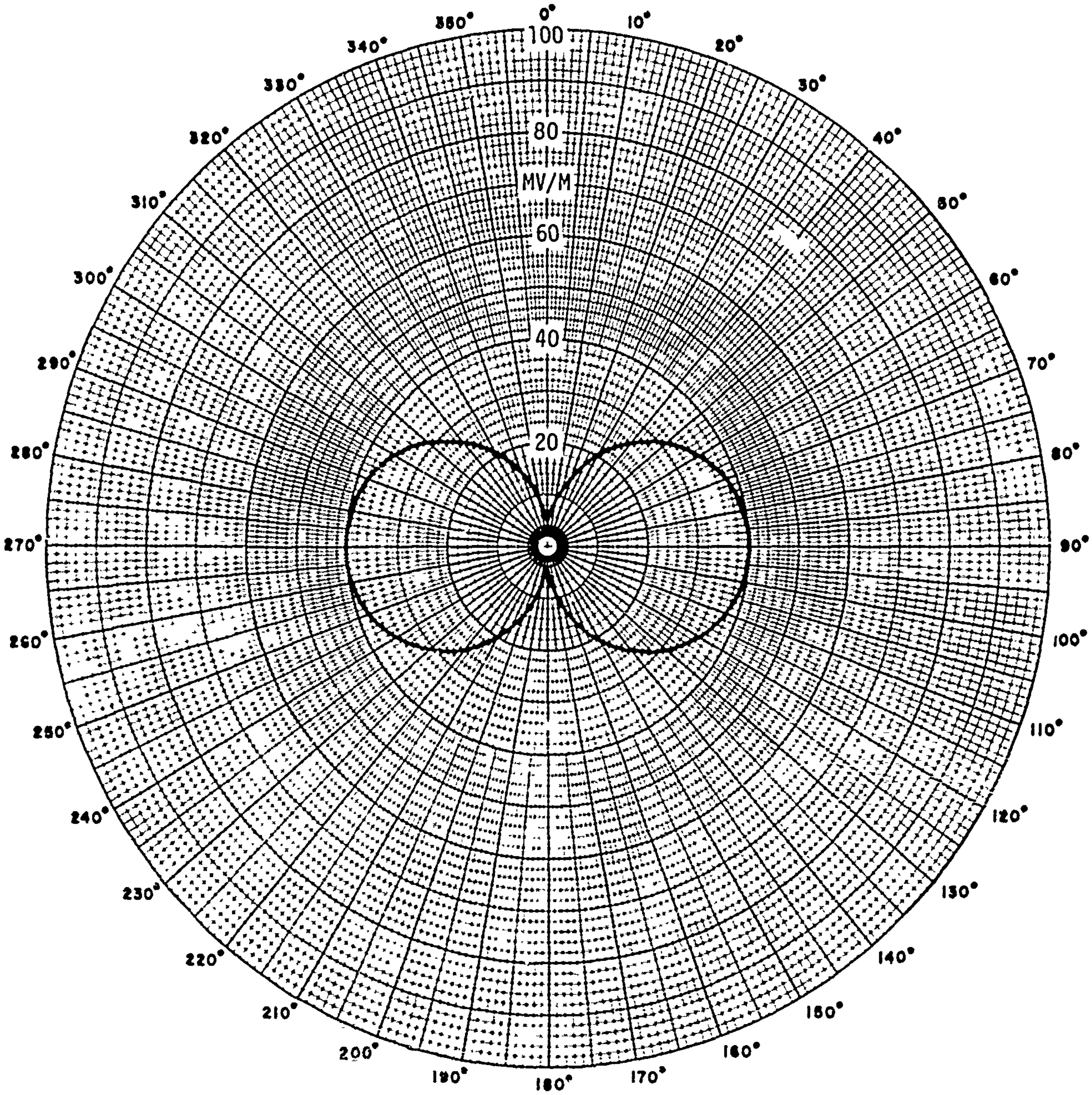


FIGURE A.5

RADIATION PATTERN
HORIZONTAL WIRE ANTENNA
1KW 540KHz

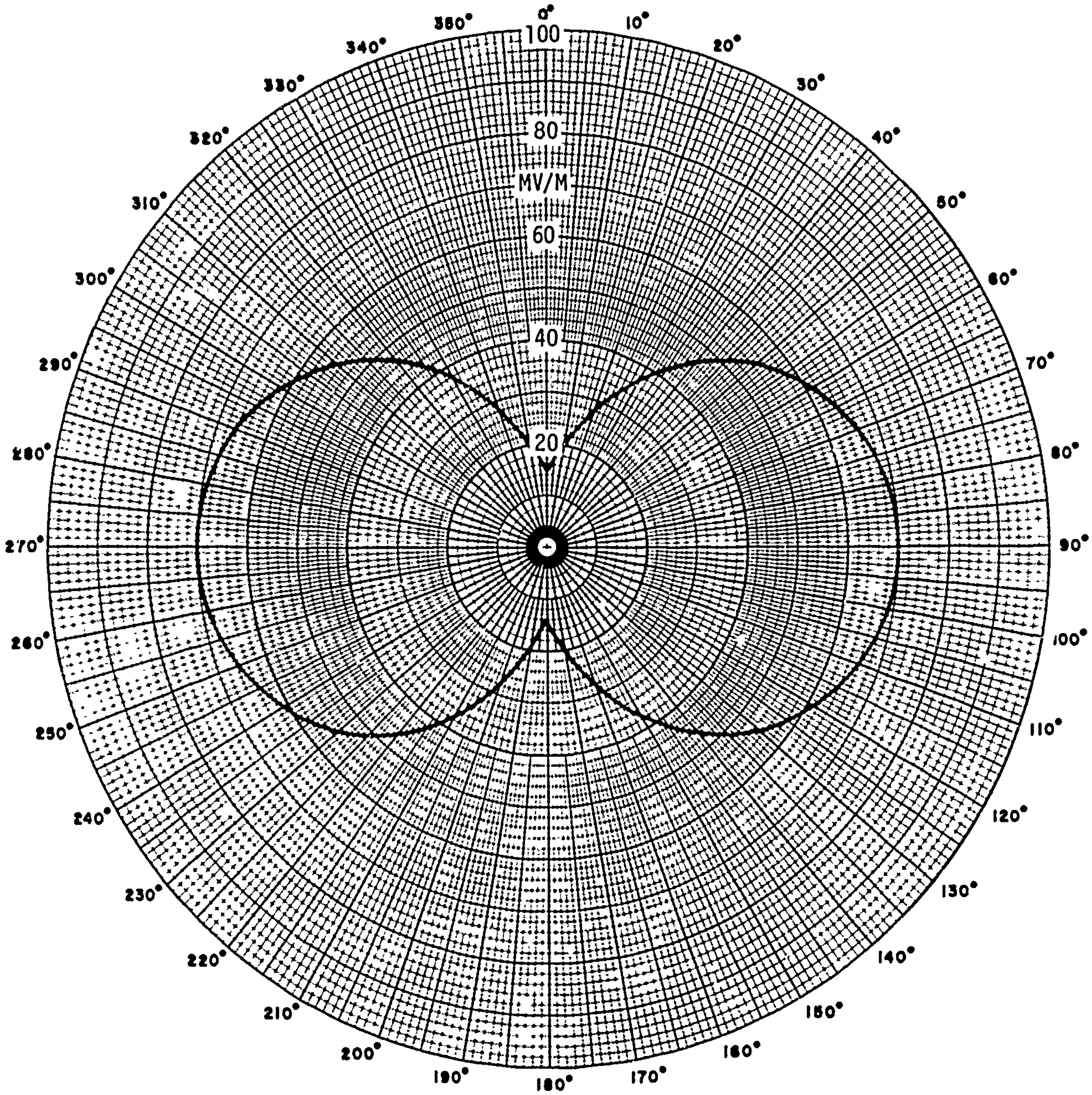


FIGURE A.6

RADIATION PATTERN
HORIZONTAL WIRE ANTENNA
1KW 1000KHz

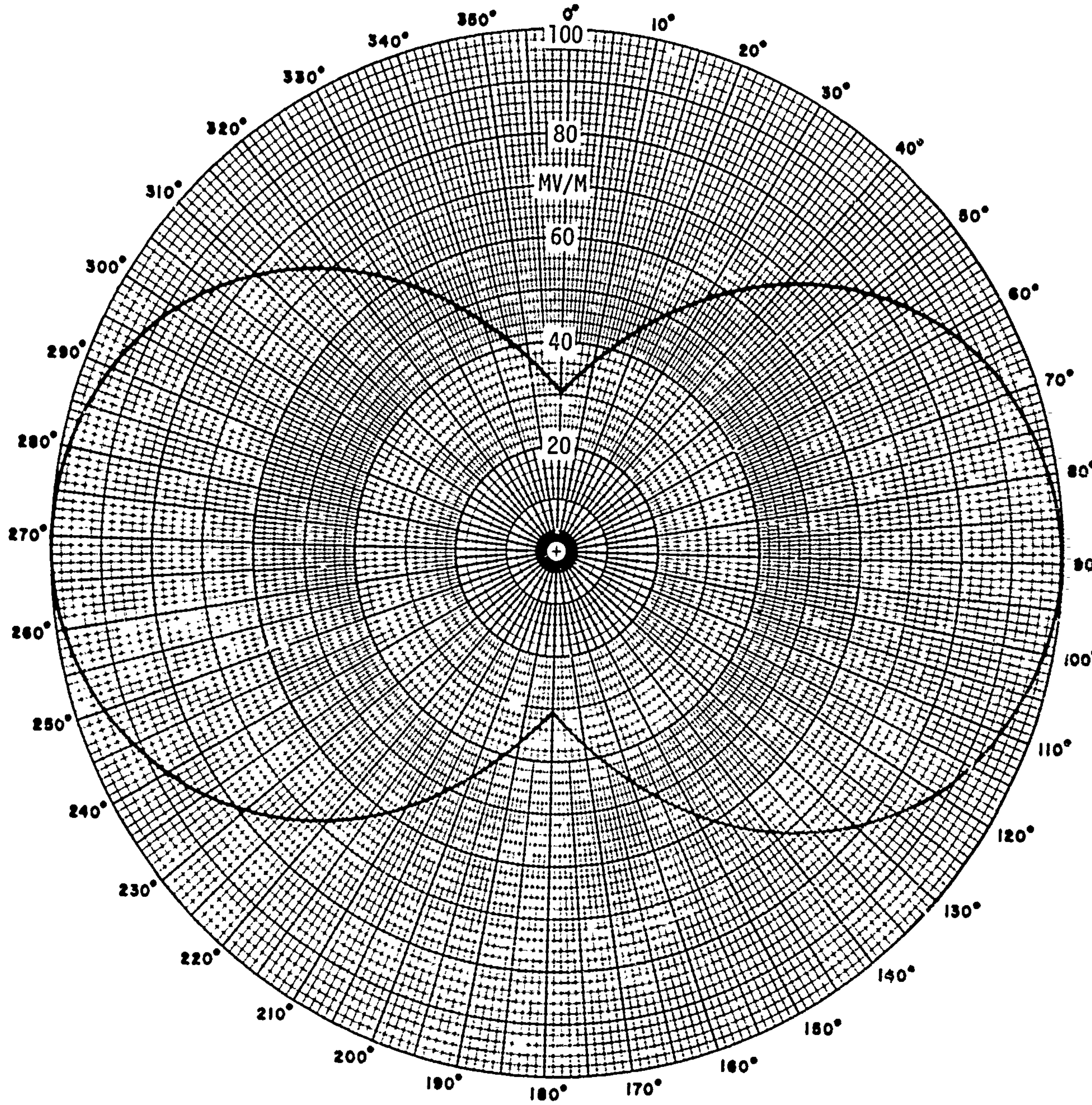


FIGURE A.7

RADIATION PATTERN
HORIZONTAL WIRE ANTENNA
1KW 1600KHz

Distance to Contour

1 KW - 540 KHz

Ø	E(mv/m)	Distance to Contour (0.5 mv/m) 2 MMHOS/M	Distance to Contour (0.5 mv/m) 8 MMHOS/M
0	5.2	6.2	9.5
10	8.6	8.8	14.5
20	14.5	12.3	20.5
30	20.5	15.0	26.5
40	26.0	17.0	31.0
50	30.8	19.0	35.0
60	34.7	20.0	38.0
70	37.6	20.6	40.0
80	39.4	21.0	40.5
90	40	21.2	41.0

1 KW - 1000 KHz

Ø	E(mv/m)	Distance to Contour (0.5 mv/m) 2 MMHOS/M	Distance to Contour (0.5 mv/m) 8 MMHOS/M
0	15.1	7.0	14.0
10	19.2	7.8	16.0
20	27.9	9.4	19.5
30	37.4	10.7	22.5
40	46.5	12.0	25.5
50	54.8	12.8	27.5
60	61.1	13.6	29.0
70	66.0	14.0	30.0
80	69.0	14.4	30.5
90	70.0	14.5	30.7

1 KW - 1600 KHz

Ø	E(mv/m)	Distance to Contour (0.5 mv/m) 2 MMHOS/M	Distance to Contour (0.5 mv/m) 8 MMHOS/M
0	30.9	6.3	13.2
10	35	6.7	14.0
20	44.9	7.6	15.7
30	56.7	8.4	17.5
40	68.5	9.2	18.8
50	79.1	9.8	20.0
60	88	10.3	21.0
70	94.6	10.7	21.5
80	98.6	10.8	21.9
90	100	11.0	22.2

Figure A.8

APPENDIX B

AM EXPEDIENT ANTENNA

PROCUREMENT SPECIFICATIONS AND INSTALLMENT INSTRUCTIONS

B.0 GENERAL

Procurement specifications have been prepared for expedient horizontal wire antennas. Separate parts lists are included for several power and frequency combinations.

Instructions for the deployment of the antennas described in procurement specifications are included.

B.1 PROCUREMENT SPECIFICATIONS

The procurement package consists of two treated wood poles installed at the transmitter site, #10 stranded copper clad steel wire, mounting hardware, insulators, and an antenna tuning unit.

Since the size of some components is dependent on power and frequency, several different parts lists are included. The parts that are independent of power and frequency are tabulated as Miscellaneous Parts on Figure B.11. Figures B.1, B.2, B.3, and B.4 list the frequency dependent parts for a power of 1 KW for the frequency ranges 540 to 750 kHz, 750 to 1000 kHz, 1000 to 1300 kHz, and 1300 to 1600 kHz respectively. Figure B.5 is a list of the parts for a 1 KW universal frequency range (540 to 1600 kHz) antenna package. Figures B.6, B.7, B.8 and B.9 are lists of the frequency dependent parts for a power of 10 KW for the frequency ranges of 540 to 750 kHz, 750 to 1000 kHz, 1000 to 1300 kHz, and 1300 to 1600 kHz respectively. Figure B.10 is a list of the parts for a 10 KW universal frequency range package.

HORIZONTAL WIRE AM ANTENNA

FREQUENCY RANGE: 540 - 750 kHz

POWER: 1 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .0024 μF, 6 KV, 10 amp	$ 20.00
1	L_2 - 53 μh, 15 amp	58.75
1	L_3 - 79 μh, 20 amp	74.75
500'	Antenna Wire	98.00
1	RF Meter 0-8 amp	67.50
1	Weatherproof housing	230.00
1	Misc. parts	425.37
	Total	974.37

FIGURE B.1

HORIZONTAL WIRE AM ANTENNA

FREQUENCY RANGE: 750 - 1000 kHz

POWER: 1 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .002 μF, 6 KV, 10 amp	$ 20.00
1	L_2 - 53 μh, 15 amp	58.75
1	L_3 - 79 μh, 20 amp	74.75
400'	Antenna Wire	80.00
1	RF Meter 0-8 amp	67.50
1	Weatherproof housing	175.00
1	Misc. parts	425.37
	Total	$900.97

FIGURE B.2

HORIZONTAL WIRE AM ANTENNA

FREQUENCY RANGE: 1000 - 1300 kHz

POWER: 1 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .0015 μF, 6 KV, 10 amp	$ 20.00
1	L_2 - 35 μh, 15 amp	45.75
1	L_3 - 47 μh, 20 amp	62.75
300'	Antenna Wire	60.00
1	RF Meter 0-8 amp	67.50
1	Weatherproof housing	175.00
1	Misc. parts	425.37
	Total	$856.37

FIGURE B.3

HORIZONTAL WIRE AM ANTENNA

FREQUENCY RANGE: 1300 - 1600 kHz

POWER: 1 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .0012 μF, 6 KV, 10 amp	$ 20.00
1	L_2 - 32 μh, 15 amp	43.75
1	L_3 - 32 μh, 20 amp	60.25
230'	Antenna Wire	45.00
1	RF Meter 0-8 amp	67.50
1	Weatherproof housing	175.00
1	Misc. parts	425.37
	Total	$836.87

FIGURE B.4

HORIZONTAL WIRE AM ANTENNA

UNIVERSAL FREQUENCY RANGE

POWER: 1 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .001 μF, 10 amp, variable	$ 262.00
1	C_{2A} - .001 μF, 10 amp	172.00
1*	C_{2B} - .001 μF, 10 amp	172.00
1	L_2 - 47 μh, 15 amp, variable	121.00
1	L_3 - 79 μh, 15 amp, variable	140.00
3	EFJ dial counters	45.00
500'	Antenna Wire	98.00
1	Weatherproof housing	250.00
1	RF Meter 0-8 amp	67.50
1	Misc. parts	425.37
	Total	$1,752.87

* not used above 1000 kHz

FIGURE B.5

HORIZONTAL WIRE AM ANTENNA

FREQUENCY RANGE: 540 - 750 kHz

POWER: 10 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .024 μF, 6 KV, 30 amp	85.00
1	L_2 - 69 μh, 30 amp	127.05
1	L_3 - 82 μh, 30 amp	134.05
500'	Antenna Wire	98.00
1	RF Meter 0-25 amp	98.00
1	Weatherproof housing	310.00
1	Misc. parts	425.37
	Total	$1,277.47

FIGURE B.6

HORIZONTAL WIRE AM ANTENNA

FREQUENCY RANGE: 750 - 1000 kHz

POWER: 10 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .002 μF, 6 KV, 30 amp	50.00
1	L_2 - 42 μh, 30 amp	115.05
1	L_3 - 69 μh, 30 amp	127.05
400'	Antenna Wire	80.00
1	RF Meter 0-25 amp	98.00
1	Weatherproof housing	310.00
1	Misc. parts	425.37
	Total	$1,205.47

FIGURE B.7

HORIZONTAL WIRE AM ANTENNA

FREQUENCY RANGE: 1000 - 1300 kHz

POWER: 10 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .0015 μF, 6 KV, 30 amp	$ 50.00
1	L_2 - 28 μh, 30 amp	74.55
1	L_3 - 42 μh, 30 amp	115.05
300'	Antenna Wire	60.00
1	RF Meter 0-25 amp	98.00
1	Weatherproof housing	244.00
1	Misc. parts	425.37
	Total	$1,066.97

FIGURE B.8

HORIZONTAL WIRE AM ANTENNA

FREQUENCY RANGE: 1300 - 1600 kHz

POWER: 10 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .0012 μF, 6 KV, 30 amp	$ 50.00
1	L_2 - 22 μh, 30 amp	72.55
1	L_3 - 42 μh, 30 amp	115.05
230'	Antenna Wire	45.00
1	RF Meter 0-25 amp	98.00
1	Weatherproof housing	244.00
1	Misc. parts	425.37
	Total	$1,049.97

FIGURE B.9

HORIZONTAL WIRE AM ANTENNA

UNIVERSAL FREQUENCY RANGE

POWER: 10 KW

QUANTITY	DESCRIPTION	COST
1	C_2 - .001 μF, 15 amp, variable	$ 286.00
1	C_{2A} - .001 μF, 15 amp	252.00
1*	C_{2B} - .001 μF, 15 amp	252.00
1	L_2 - 69 μh, 30 amp, variable	219.00
1	L_3 - 82 μh, 30 amp, variable	228.00
3	EFJ dial counters	45.00
500'	Antenna Wire	98.00
1	Weatherproof housing	310.00
1	RF Meter 0-25 amp	98.00
1	Misc. parts	425.37
	Total	$2,213.37

* not used above 1000 kHz

FIGURE B.10

HORIZONTAL WIRE AM ANTENNA

MISCELLANEOUS PARTS

QUANTITY	DESCRIPTION	COST
2	Wood poles, 35' high, installed	$280.00
1	Bowl insulators	20.00
30	Pole steps	60.00
1	Spool insulator	.46
2	Strain insulators	.96
1	Clevis, with spool	.78
1	Cleat	.35
1	Anchor stake	1.42
12	"U" bolt/clamp (for #10 wire)	.60
10'	4" copper strap	10.00
1	"J" plug	18.00
10'	2" copper strap	6.00
75'	Nylon hoist line	20.00
1	Anchor shackle	2.00
12	1" C clamps	4.80
	Total	$425.37

FIGURE B.11

The component prices are based on current manufacturer's catalogs. The cost of procuring and erecting the wood poles will vary with locality. The labor cost of assembling the components into an expedient antenna package is not included.

B.2 INSTALLATION INSTRUCTIONS: AM EMERGENCY ANTENNA

B.2.1. GENERAL

This emergency antenna kit contains, with the exception of support poles, the complete assortment of hardware and materials necessary for the deployment of a useable emergency antenna system. The emergency antenna will consist of a nearly horizontal, quarter wave radiator supported approximately thirty feet above ground and the minimum coupling circuitry required to match antenna impedance to the transmitter. Since the existing ground radials will be an essential component of the emergency antenna system, it is important that the coupling point be centrally located with respect to the ground radials despite the difficulties which may be encountered with the remains of the fallen tower.

Deployment will be accomplished in two phases, Preliminary Preparation and Emergency Deployment. Preliminary preparations are to be carried out as soon as the kit is received and will consist mainly of procuring and installing two support poles. Pole steps and wire holders are required to be installed prior to setting the poles as a convenience and to save time should emergency deployment become necessary.

Emergency deployment will be made only after the original antenna system has been damaged beyond use and will consist principally of installing a wire radiating element on the support poles and coupling the antenna to the transmitter.

The following installation instructions are of necessity broad in application because of the great variety of conditions which may exist at

individual AM broadcast stations especially under circumstances where the emergency antenna will be required. It is anticipated, however, that given the materials and these limited instructions the average radio technician will be capable of placing his station back on the air to at least partially serve the normal coverage area. The goal is to restore service within thirty minutes.

Figure B.12 is a drawing of the expedient antenna. Installation details are shown.

B.2.2. PRELIMINARY PREPARATION

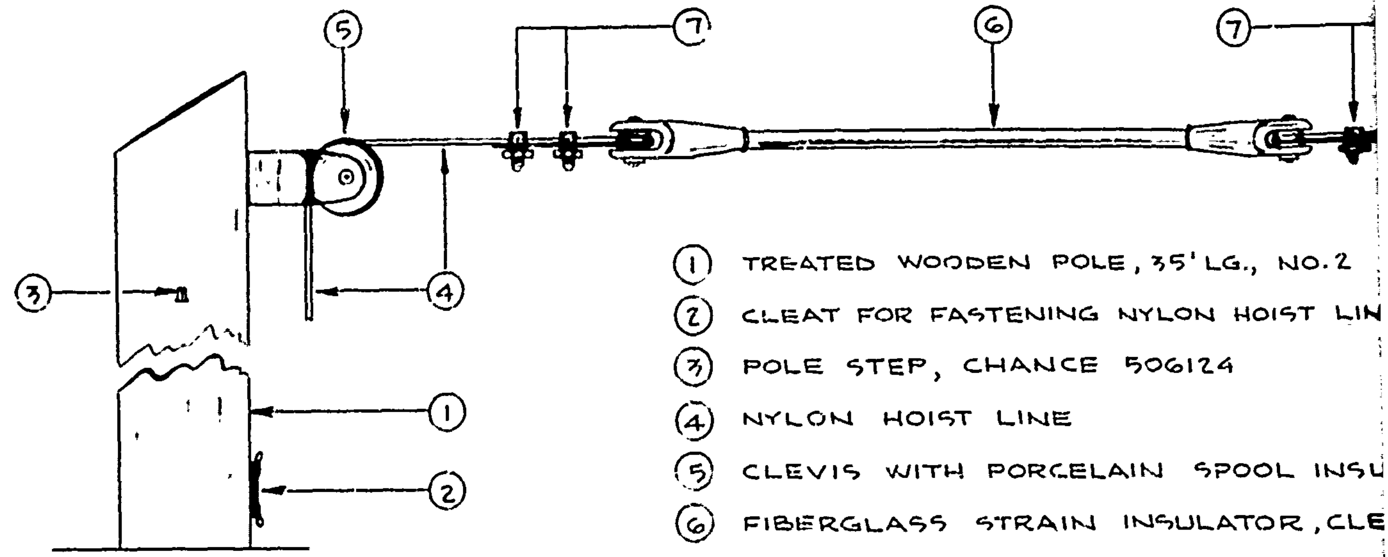
Step 1. Procure two treated, thirty-five foot wooden poles and the services of a local contractor to set the poles upright in the ground.

Step 2. Starting ten feet from the butt end of Pole No. 1 install a total of eight pole steps along one side at three foot intervals. Starting eleven feet six inches from the butt install seven pole steps at three foot intervals along the opposite side. This will provide staggered steps eighteen inches apart. Repeat this procedure for Pole No. 2.

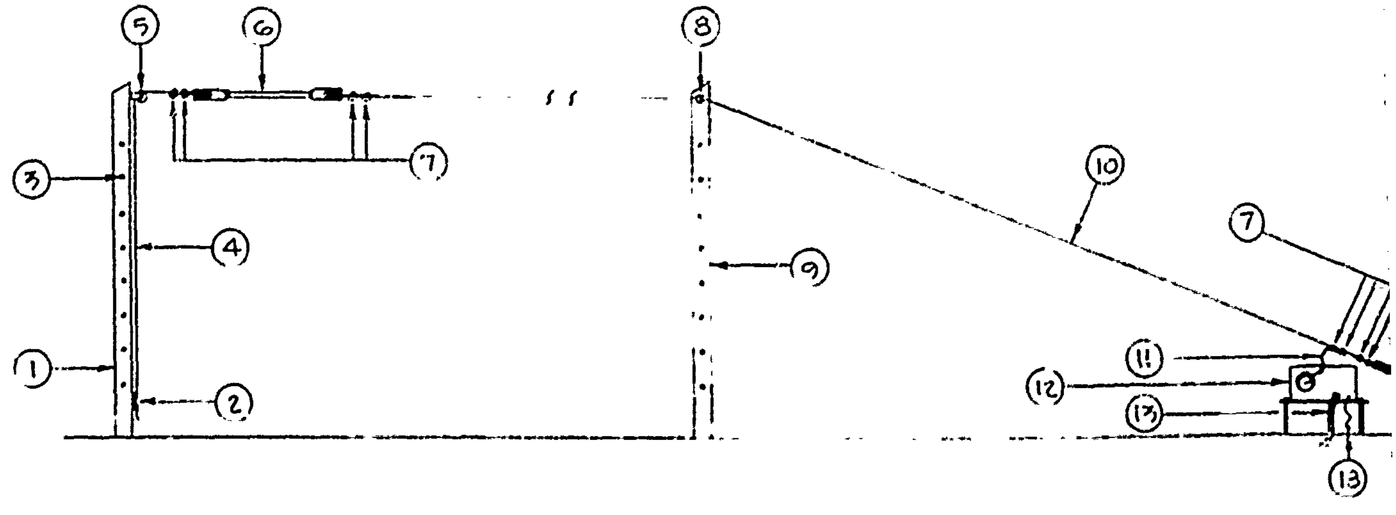
Step 3. Install the spool insulator six inches from the top of Pole No. 1 as shown in the diagram.

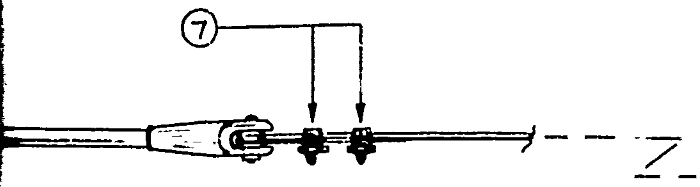
Step 4. Install the clevis with spool six inches from the top of Pole No. 2 as shown in the diagram.

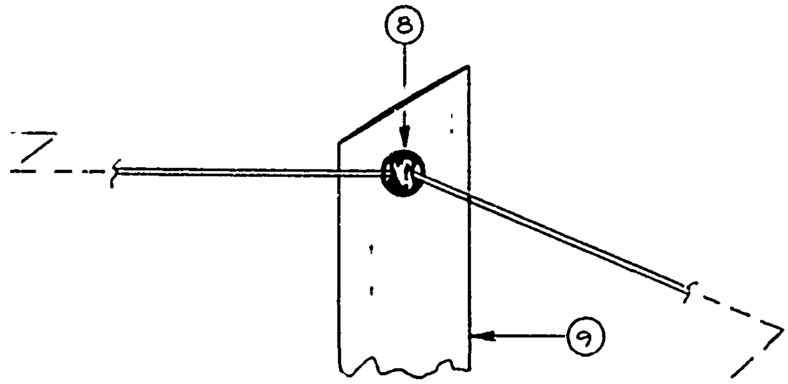
Step 5. Select and stake out a line originating at the original antenna tuning unit on a bearing approximately 90° to the direction of greatest population density in the service area. (In a multi-element array use the ATU nearest the transmitter building.)



1. TREATED WOODEN POLE, 35' LG., NO. 2
2. CLEAT FOR FASTENING NYLON HOIST LIN
3. POLE STEP, CHANCE 506124
4. NYLON HOIST LINE
5. CLEVIS WITH PORCELAIN SPOOL INSU
6. FIBERGLASS STRAIN INSULATOR, CLE
7. SPLIT BOLT CONNECTOR (CABLE CLAMP) WITH SPACER, GRAYBAR 9F
8. WIRE HOLDER, CHANCE 0621
9. TREATED WOODEN POLE, 35' LG., NO. 1
10. ANTENNA WIRE
11. ANTENNA FEED
12. ATU (ANTENNA TUNING UNIT)
13. TRANSMISSION LINE
14. FIBERGLASS STRAIN INSULATOR CLEVIS - TONGUE FITTING, CHANCE 16







POLE, 35' LG., NO.2

ING NYLON HOIST LINE

ICE 506124

E

CELAIN SPOOL INSULATOR, CHANCE 0341-0606

AIN INSULATOR, CLEVIS FITTING BOTH ENDS, CHANCE 16CC·24

SPACER, GRAYBAR 9FB

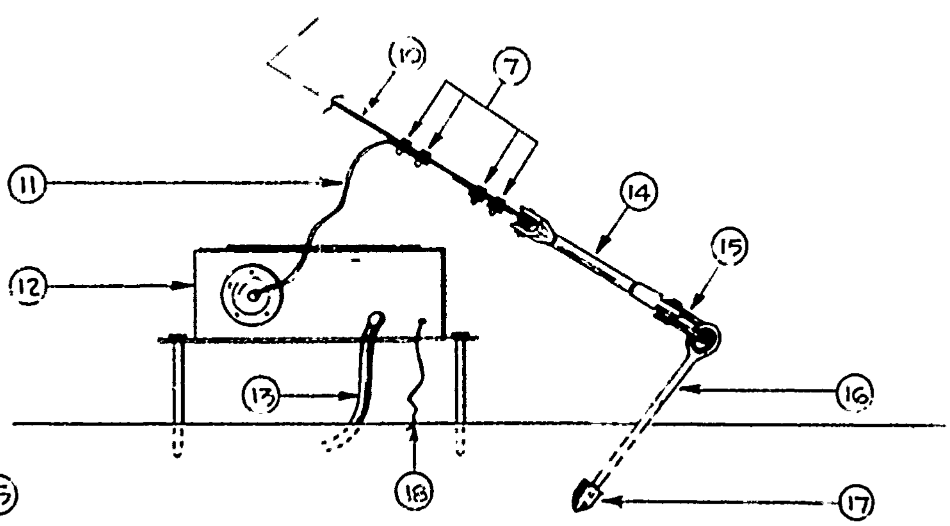
(15) ANCHOR SHACKLE, CHANCE 5801

(16) ANCHOR STAKE, CHANCE 6415

(17) DRIVE POINT (FOR ANCHOR STAKE), CHANCE 15232

(18) GROUND STRAP

FITTING, CHANCE 16TC-24



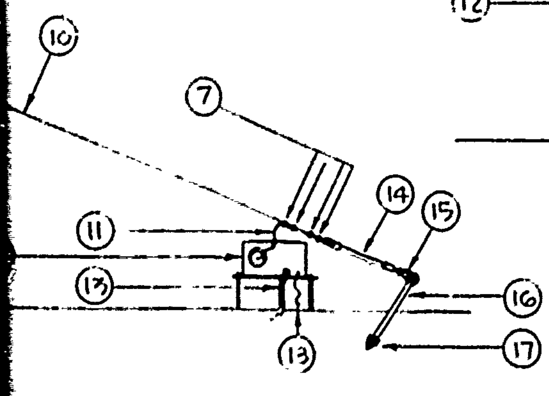


FIGURE B.12
DETAIL DRAWING
AM EXPEDIENT ANTENNA

B

Step 6. Set Pole No. 1 on the line seventy-five feet from the ATU.

Step 7. Set Pole No. 2 at a distance from Pole No. 1 such that the total antenna wire length (the slant segment plus the horizontal) will equal 0.2375 wave lengths at the operating frequency. This distance may be determined from Figure B.13 which is a graph of required pole separation vs. frequency.

Step 8. Install the Cleat on Pole No. 2 directly under the insulated pulley and approximately five feet above ground. This completes preliminary preparations.

B.2.3 EMERGENCY DEPLOYMENT

Step 1. Remove contents of kit and check parts against parts list, Figure B.14. Deficiencies, if any, should be made up from components available at the station.

Step 2. Select a location for the emergency antenna tuning unit where the terminal end of the transmission line may be connected to the terminal provided in the emergency antenna tuning unit. (The installer should make every effort to achieve a direct connection, but should this be impossible an extension of the center conductor must be improvised using a short length of transmission line or other type of conductor.) The extension should not exceed five feet in length.

Step 3. Set the emergency ATU in place and bond the copper ground strap to the existing ground system making contact with as many radial wires as possible. Contact points should be cleaned and soldered. Should soldering equipment not be available the "C" clamps provided in the kit should be used for firm ground connections. If a center-conductor extension as described in Step 2 is necessary, a ground strap connecting the outer

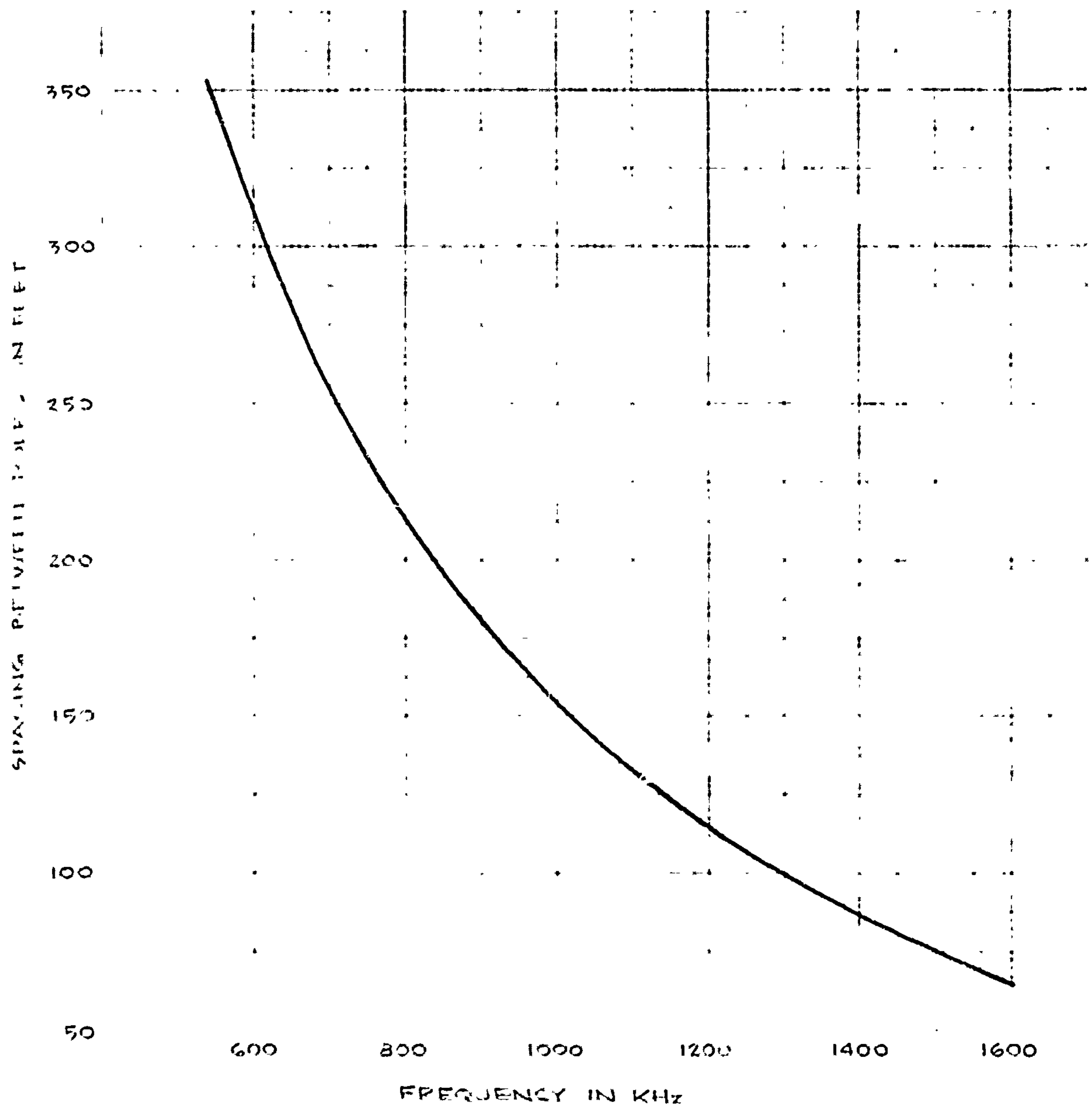


FIGURE B.13

SPACING VS FREQUENCY

PARTS LIST

PART NO.		QUANTITY
1.	35' pole (not included)	2 ea.
2.	Pole Steps	30 ea.
3.	Spool Insulator	1 ea.
4.	Clevis, with Spool	1 ea.
5.	Cleat	1 ea.
6.	Antenna Tuning Unit	1 ea.
7.	Copper Strap (4")	10'
8.	Copper Strap (2")	10'
9.	"C" Clamp (1")	12 ea.
10.	Anchor Stake	1 ea.
11.	Strain Insulator (Fiber-glass)	2 ea.
12.	Anchor Shackle	1 ea.
13.	Antenna Wire	1 ea.
14.	Cable Clamps	12 ea.
15.	Nylon Hoist Line	1 ea.

FIGURE B.14

EXPEDIENT ANTENNA PACKAGE

conductor of the existing transmission line to the emergency ATU ground strap must be installed.

Step 4. Select a point for the anchor stake near the ATU on the side containing the bowl insulator. Drive the anchor stake approximately four feet into the ground at an angle of twenty-five degrees from the vertical slanting away from the direction of Pole No. 1. This should leave twelve inches of the stake protruding above the surface.

Step 5. Attach one of the twelve inch fiber-glass insulators to the eye in the top of the anchor stake. An anchor shackle is provided in the kit for this purpose.

Step 6. Roll out the antenna wire on the ground between the anchor stake and Pole No. 2. Pass the near end through the spool insulator on Pole No. 1 back to the ground and pull sufficient wire to comfortably reach the anchor stake.

Step 7. Attach the second twelve inch fiber-glass insulator to the end of the antenna wire nearest Pole No. 2 by forming a loop through an eye in the insulator and securing the connection with a pair of cable clamps. Secure an end of the nylon hoist line to the other eye in the fiber-glass insulator.

Step 8. Pass the free end of the nylon hoist line through the clevis on Pole No. 2 back to ground. Hoist the fiber-glass insulator to within approximately two feet of the pulley and tie off to the cleat.

Step 9. Pass the opposite end of the antenna wire through the open eye of the insulator attached to the anchor stake and pull the excess through. When most of the slack has been taken up, form a loop and secure the connection with a pair of cable clamps.

Step 10. Return to Pole No. 2, loosen the hoist line and draw additional slack out of the wire until not more than a two foot sag remains at the midpoint between the poles. At this point the fiber-glass insulator should have been drawn close to the clevis spool at the top of Pole No. 2. If the insulator jams in the clevis before the wire pulls taut or, conversely, if the wire pulls taut before the fiber-glass insulator is within a foot or two of the clevis, slack the hoist line, make an appropriate length adjustment at the anchor stake end of the antenna wire and re-tighten. When the antenna wire has been properly adjusted for length and sag, tie the hoist line off to the cleat and trim off the excess wire at the anchor stake connection. Additional sag which may occur during operation may be removed by further adjustment of the hoist line.

Step 11. Connect the center shaft of the bowl insulator to the antenna wire. This connection should be made above and within two feet of the fiber-glass insulator. The lead should be kept as short as possible. A two inch copper strap has been provided for fabrication of the lead.

B.2.4 MATCHING IN

Step 1. Adjust the transmitter for the lowest power output and apply power to the emergency antenna, carrier only. Tune the transmitter for best operating conditions, record the antenna current indicated by the base current ammeter in the emergency antenna tuning unit and turn off the transmitter. Open the emergency antenna tuning unit and move the tap on the series coil one turn in either direction. Close the ATU, turn on the transmitter and again note the antenna current. If the antenna current has increased continue to adjust until maximum antenna current has been achieved. Should

the current decrease upon the first adjustment reverse direction and adjust for maximum antenna current.

Step 2. When maximum antenna current has been achieved re-tune the transmitter for best operation and increase power to the normal level. If the transmitter behaves in a normal or near normal manner and is capable of being modulated normally no further adjustment of the ATU is required and emergency operations may be initiated.

Step 3. Should the transmitter not behave normally further adjustment is required. Turn the transmitter off and re-adjust for lowest practical power output. Move the tap on the ATU shunt coil one turn in either direction and adjust for maximum antenna current as described in Step 2. Turn on the transmitter and check tuning conditions. If conditions have been improved continue to adjust the shunt coil gradually, until best operating conditions have been attained. Adjustments in the series coil will be necessary during the shunt adjustments to maintain antenna current. As a rule of thumb, a turn added to one will result in the necessity to remove a turn from the other.

APPENDIX C

FM EXPEDIENT ANTENNA

PROCUREMENT SPECIFICATIONS AND INSTALLATION INSTRUCTIONS

C.0 GENERAL

Procurement specifications have been prepared for FM antennas. Separate parts lists are included for two power levels.

Instructions for the deployment of the antenna described in the procurement specifications are included.

C.1 PROCUREMENT SPECIFICATIONS

The procurement package consists of a treated wood pole installed at the transmitter site, an FM antenna, and transmission line.

Figure C.1 is a list of the parts for a nominal 1 KW antenna package and Figure C.2 is a list of the parts for a nominal 5 KW package. The actual power capacity of the antenna is dependent on the number of bays and the transmission line diameter. Actual maximum powers are about 3 KW and 6 KW respectively.

The effective radiated power of an FM station is the product of the input power and the antenna gain. The antenna gain is approximately the number of bays. The package C.1 specifies a one bay antenna while package C.2 uses a two bay. Thus, for the same input power, package C.2 would produce about twice the radiated power as package C.1 It would be desirable to supply package C.2 to all protected stations.

Component prices are based on current manufacturer's catalogs. The cost of procuring and erecting the wood pole will vary with locality. The labor cost of assembling the components into an expedient antenna package is not included.

EXPEDIENT FM ANTENNA

POWER: 1 KW

QUANTITY	DESCRIPTION	COST
1	Antenna - Gates FMA-1A*	$567.00
70'	7/8" Foam Heliax*	128.80
1	35' wood pole, installed	140.00
15	Pole steps	30.00
2	End flange	49.20
2	Line Reducer (1-5/8" to 7/8")	112.00
75'	Nylon hoist line	20.00
12'	2" Galvanized pipe	8.00
2	Pipe clamps	9.00
1	Pulley with bracket	12.00
1	Transmission line hanger kit	18.50
1	Cleat	.35
	Total	$1,094.85

* or equivalent

FIGURE C.1

EXPEDIENT FM ANTENNA

POWER: 5 KW

QUANTITY	DESCRIPTION	COST
1	Antenna - Gates FMA-2A*	$1,105.00
70'	1-5/8" Foam Heliax*	243.60
1	35' wood pole, installed	140.00
15	Pole steps	30.00
2	End flange	136.00
75'	Nylon Hoist Line	20.00
12'	2" Galvanized pipe	8.00
2	Pipe clamps	9.00
1	Pulley with bracket	12.00
1	Transmission line hanger kit	18.50
1	Cleat	.35
	Total	$1,722.45

* or equivalent

FIGURE C.2

C.2 INSTALLATION INSTRUCTIONS: FM EMERGENCY ANTENNA

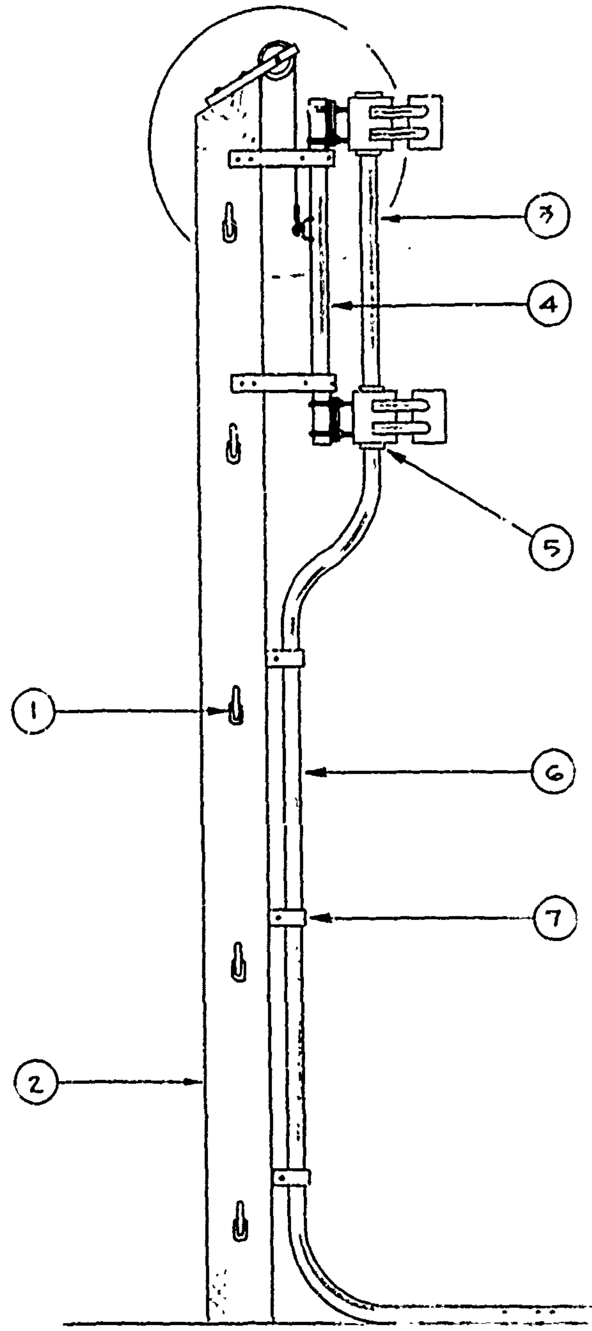
C.2.1 GENERAL

This emergency antenna kit contains, with the exception of the support pole, the complete assortment of hardware and materials necessary for the deployment of a usable emergency FM antenna. The emergency antenna will consist of a standard single bay FM antenna for transmitter power outputs up to 1 KW or a two-bay antenna for powers from 1 KW up to 5 KW and sufficient transmission line with fittings to couple the antenna to the transmitter.

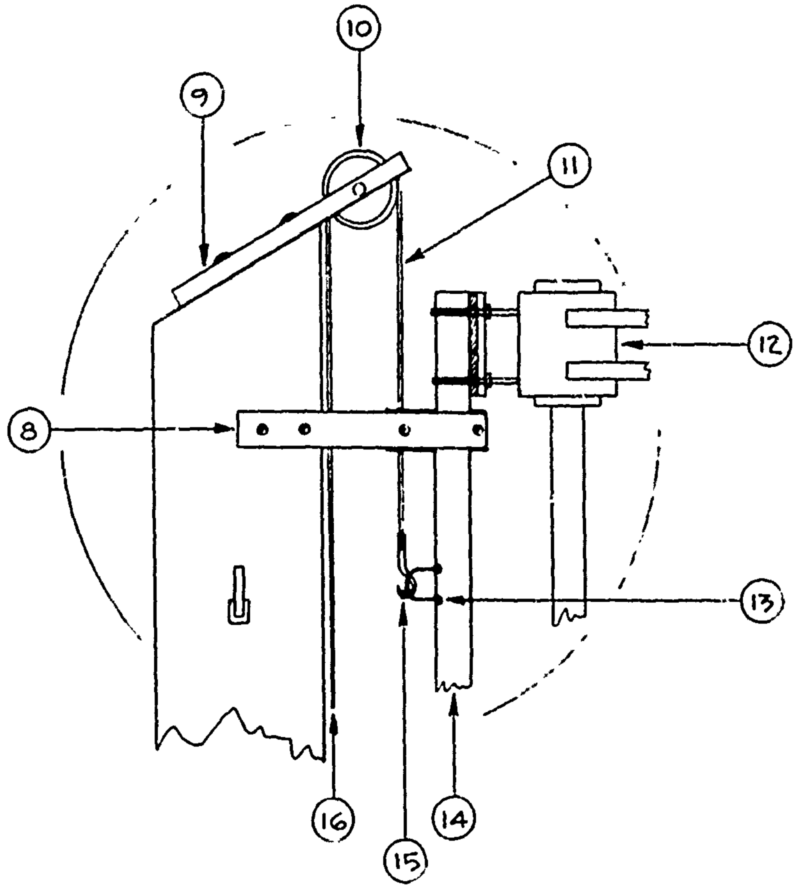
Deployment will be accomplished in two phases; Preliminary Preparation and Emergency Deployment. Preliminary Preparation is to be carried out as soon as the kit is received and will consist mainly of procuring and installing the support pole, pole steps, antenna mounting brackets and transmission line hangers. Emergency Deployment will be carried out only after the original antenna has been damaged beyond use and will consist principally of installing the emergency FM antenna and transmission line.

The following installation instructions are of necessity broad in application because of the great variety of conditions which exist at individual FM broadcast stations. It is anticipated, however, that given the materials and these limited instructions the average radio technician will be capable of placing his FM station back on the air to offer at least partial coverage to his normal service area. The goal is to restore service within thirty minutes.

Figure C.3 is a drawing of the two-bay expedient antenna, showing installation details. Reference to this drawing should be helpful in deployment of the single or two-bay unit.



1. POLE STEPS
2. POLE
3. RIGID 1 5/8" LINE
   2 BAYS (FOR 5 KW)
4. SINGLE BAY (1 KW) WILL BE MO
   ABOUT CENTER BETWEEN PIPE C
5. 1 5/8" EIA FLANGE
6. TRANSMISSION LINE
7. TRANSMISSION LINE HANGE
8. PIPE CLAMP (2")



OLE STEPS		9	BRACKET
OLE		10	PULLEY
IGID 1 5/8" LINE BAYS (FOR 5 KW) NGLE BAY (1 KW) WILL BE MOUNTED OUT CENTER BETWEEN PIPE CLAMPS		11	ROPE
		12	GATES FM ANTENNA
/8" EIA FLANGE		13	EYELET WELDED TO PIPE
ANSMISSION LINE		14	GALVANIZED 2" WATER PIPE
ANSMISSION LINE HANGERS		15	HOOK
E CLAMP (2")		16	NYLON ROPE TO CLEAT

FIGURE C.3
DETAIL DRAWING
FM EXPEDIENT ANTENNA

B

C.2.2 PRELIMINARY PREPARATION

Step 1. Procure a treated, thirty-five foot wooden pole and the services of a local contractor to set the pole upright in the ground.

Step 2. Starting ten feet from the butt end install a total of eight pole steps along one side at three foot intervals. Starting eleven feet six inches from the butt install seven pole steps at three foot intervals along the opposite side. This will provide staggered steps eighteen inches apart.

Step 3. Install the pulley with bracket on the tip end of the pole as shown in Figure C.3.

Step 4. Install one of the pipe clamps twelve inches from the tip end of the pole. Install the second pipe clamp five feet below the first for a single bay antenna. For a two-bay antenna measure the distance separation between the bays and install the second pipe clamp below the first, the distance separation less two feet.

Step 5. Install the transmission line hangers in accordance with directions in the hanger kit.

Step 6. Set the pole near the transmitter so that the seventy feet of transmission line in this kit will suffice. Setting depth is five feet.

Step 7. Install the cleat approximately five feet above ground.

Step 8. Install the end flanges on the transmission line and in the case of the single bay antenna also install the line reducer units to adapt the smaller line to the antenna and transmitter connections.

Step 9. Assemble the FM antenna on the two inch galvanized pipe, aligning the top bay of the two-bay antenna with the top end of the pipe.

Assemble the single bay antenna approximately eighteen inches below the top end of the pipe. Store the antenna and transmission line in a secure place. This completes preliminary preparation.

C.2.3 EMERGENCY DEPLOYMENT

Step 1. Lay out the transmission line on the ground at the base of the pole and attach one end to the antenna connection.

Step 2. Make one end of the hoist line fast to the eye on the galvanized pipe and pass the free end through the pulley at the top of the pole.

Step 3. Hoist the antenna into position and tie off the hoist line to the cleat.

Step 4. Clamp the galvanized pipe in the pipe clamps previously installed on the pole.

Step 5. Connect the free end of the transmission line to the transmitter.

APPENDIX D

EXPEDIENT ANTENNA CONSTRUCTION

D.0 GENERAL

The purpose of this monograph is to describe techniques useful in the construction of an expedient AM antenna system under emergency conditions. It is assumed that the normal antenna has been destroyed during an emergency and that no pre-packaged emergency antenna is available. The station's technician is to restore limited service using only parts and tools as may be available.

The basic steps in restoring service are damage assessment, physical construction, adjustment, and operation. Each of these steps is critical to restoring maximum service in the shortest possible time. Time is more important than radiated power, so an inefficient operation in 15 minutes is better than full power in two hours.

D.1 DAMAGE ASSESSMENT

The first step is to discover how much of the antenna system has been destroyed. Presumably a tower has fallen. If you have a directional antenna system and one of the towers is intact, use it as a non-directional antenna. It will be a better expedient antenna than any antenna you can construct in a short time.

Check the antenna tuning unit and the transmission line. A tuning unit will be necessary to couple to the antenna. If the normal unit is not severely damaged, it can be used. If it is damaged beyond use, salvage any components that may be useful to build another tuning unit.

The transmission line is necessary to connect from the transmitter to the antenna tuning unit. Check for any breaks. It will be necessary to splice breaks. If the transmission line is broken in several places or damaged beyond repair, it will be necessary to use another transmission line or locate the antenna feed point near the transmitter. The phase sampling line of a directional station can be used as a transmission line for power up to about 1 KW.

D.2 PHYSICAL CONSTRUCTION

The only antenna that one person can reasonably construct within a very short time under emergency conditions is an elevated horizontal or slant wire antenna. Figure D.1 is a sketch of an elevated wire antenna. The nature of the antenna will depend on the types of materials available, the surrounding objects that can be used as supports and the ingenuity of the technician. The important initial decisions are the location of the antenna feed point and the orientation and length of the antenna.

In order to provide a good ground the antenna feed point should be located near the base of the fallen tower. If the regular tuning unit is intact, the expedient antenna can be fed directly from the tuning unit. If the transmission line has been destroyed beyond repair and no other transmission line is available the feed point will have to be located near the transmitter. It is possible to construct a transmission line, but don't try. The performance of an antenna fed at a transmitter without a good ground will probably be better than the performance with a good ground and an improvised transmission line.

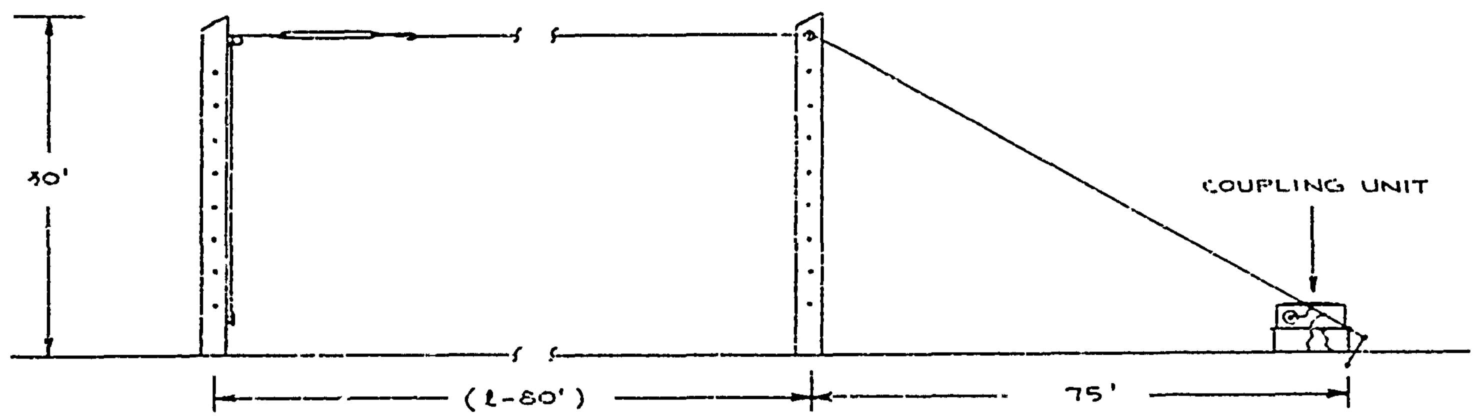


FIGURE D.1

SKETCH OF HORIZONTAL WIRE ANTENNA

The ideal orientation of the antenna is broadside to the area you need to serve, however, if supporting structures are readily available for other orientations do not waste time building new supports. You can always construct a better antenna after restoring some service.

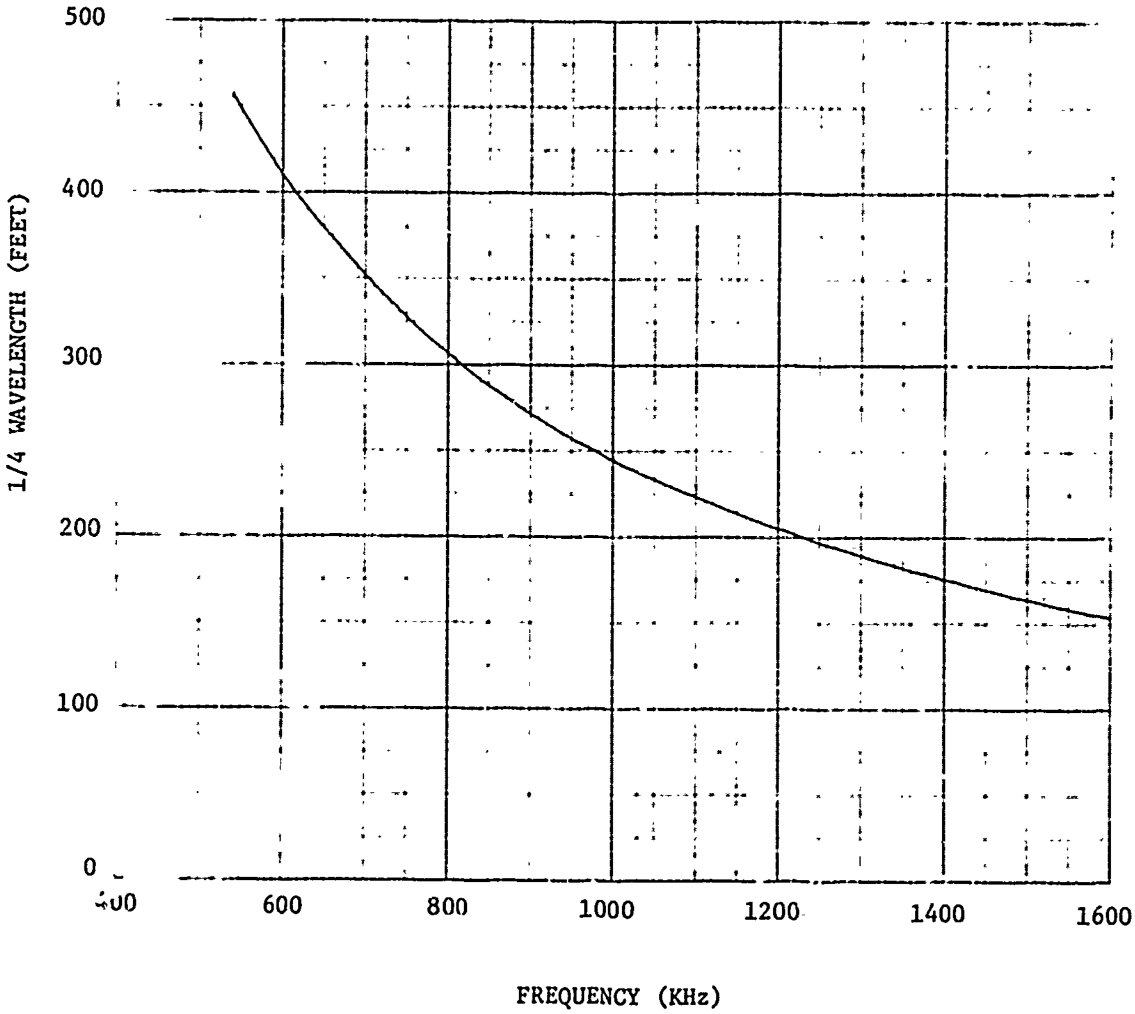
The first choice for the length of the expedient antenna is the height of the regular antenna. The input impedance of the expedient antenna will be almost identical to the impedance of the regular antenna and the regular antenna tuning unit can be used with little or no adjustment.

If the regular antenna is taller than one quarter wavelength and it is not possible to support a horizontal wire antenna as long as the regular antenna then construct a quarter wavelength antenna. Figure D.2 shows the length versus frequency for a quarter wavelength.

The availability of supporting structures will to some extent determine the length and orientation of the expedient antenna. Use any existing structures available such as trees, buildings, and utility poles. A step ladder or even an automobile can be used if nothing else is available.

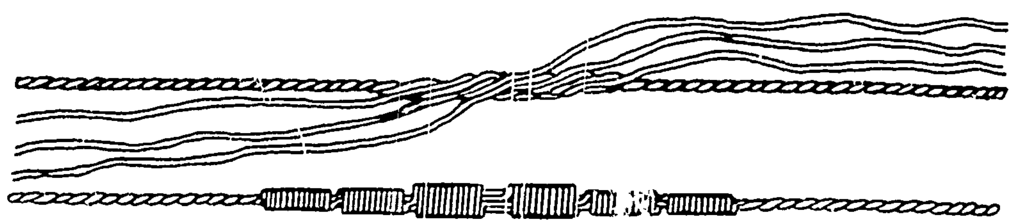
The antenna proper consists of a conductor supported on insulators and fed at one end. The conductor can be almost any wi... ...en a radial from the ground system. The wire size should be at least #14 to carry the current. If it is necessary to use two or more pieces of wire to reach the desired length, the splices must be good mechanical and electrical connections. Figure D.3 shows techniques of splicing wires. The splices should be soldered if possible.

The antenna must be insulated from ground and supporting structures. The only electrical contact to the antenna is the feed point. Figure D.4

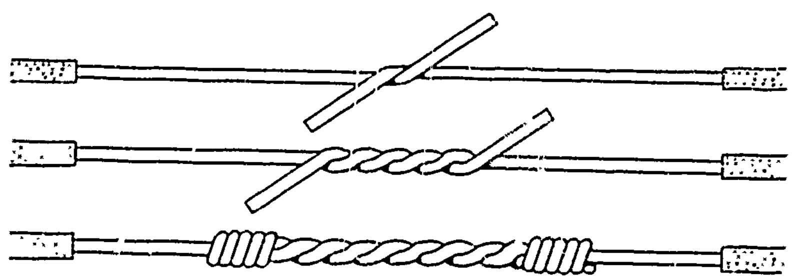


1/4 WAVELENGTH VS FREQUENCY

FIGURE D.2



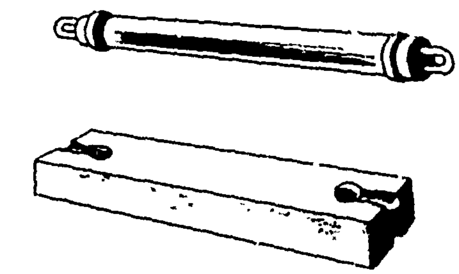
SPLICING STRANDED ANTENNA WIRE



SPLICING SOLID ANTENNA WIRE

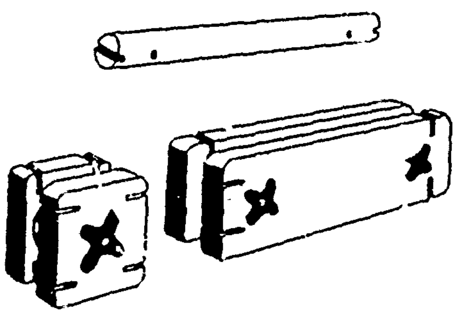
FIGURE D.3

TECHNIQUES OF SPLICING WIRES

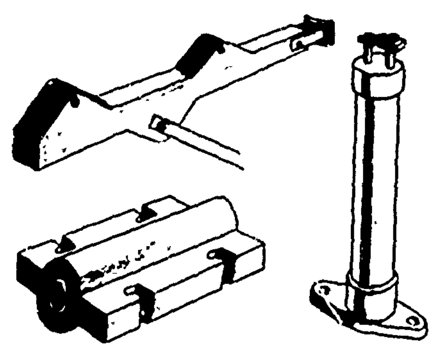


ANTENNA STRAIN INSULATORS

STRAIN INSULATOR IN STEEL WIRE



SPREADER INSULATORS



SUPPORT OR STANDOFF INSULATORS

FIGURE D.4

COMMON ANTENNA INSULATORS

shows techniques for using several types of common insulators. An insulator can be improvised from almost any plastic or nylon material. An empty soft drink bottle makes an excellent insulator. If nothing else is available dry wood can be used. Figure D.5 shows several improvised insulators.

An antenna tuning unit is usually necessary to couple to the antenna. If the regular tuning unit is usable, use it. If the regular unit is unusable, construct an L network. Figure D.6 is a sketch of an L network used as an antenna tuning unit and Figure D.7 is a tabulation of the approximate initial adjustment of the coils.

D.3 ADJUSTMENT

The antenna tuning unit should be adjusted to match the transmitter to the antenna as well as possible. If an RF impedance bridge is available, measure the input impedance to the antenna tuning unit and adjust the coils to produce the best match possible.

Without an impedance bridge, the antenna tuning unit is adjusted to produce the maximum antenna current. Reduce the transmitter output power to a minimum and proceed with the following steps:

a. Turn on power and observe antenna current.

b. Turn off transmitter and move L_2 one turn.

c. Repeat a and b until maximum current is achieved.

d. Turn off transmitter and move L_3 one turn.

e. Turn on transmitter and observe antenna current.

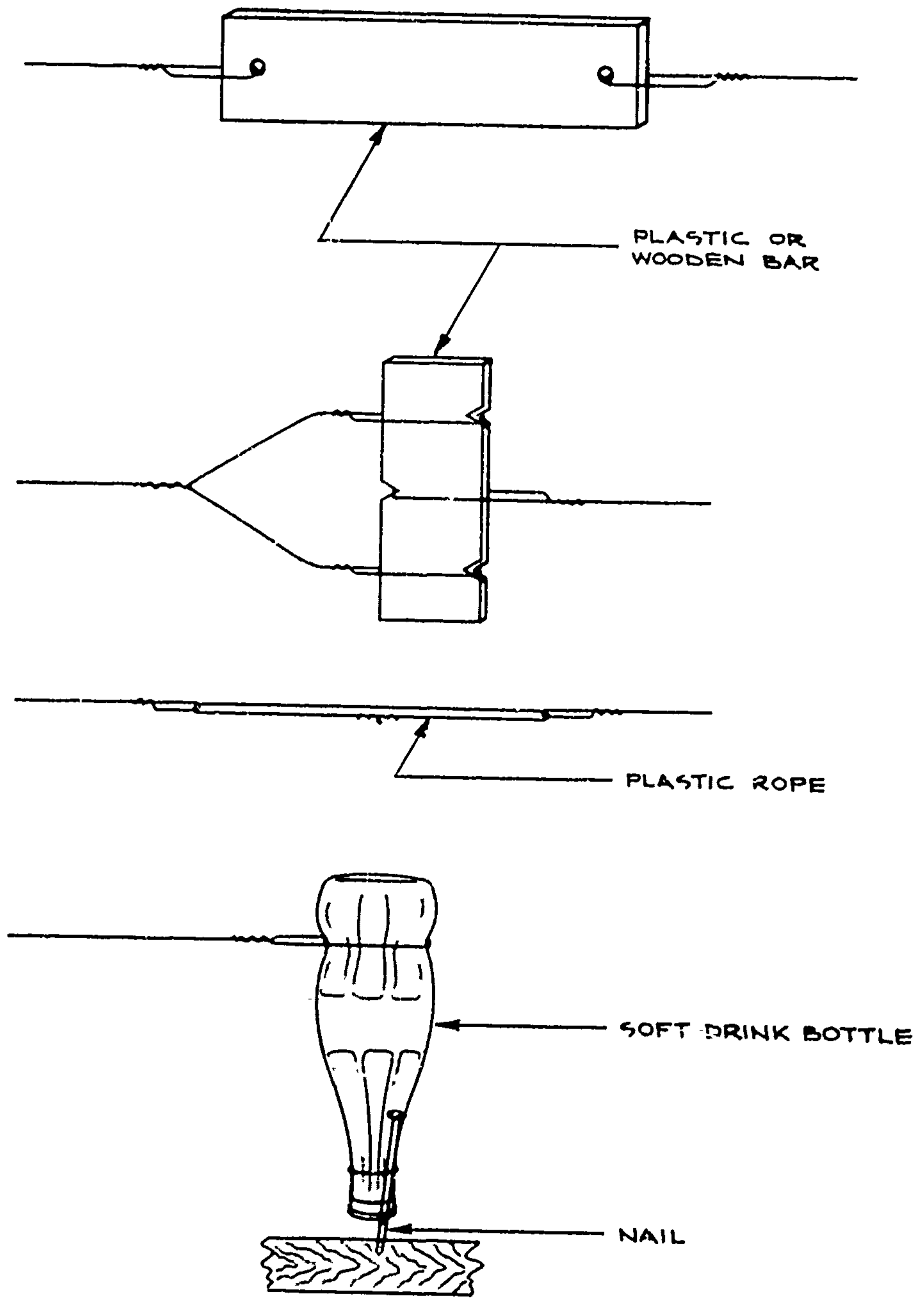


FIGURE D.5
IMPROVISED INSULATORS

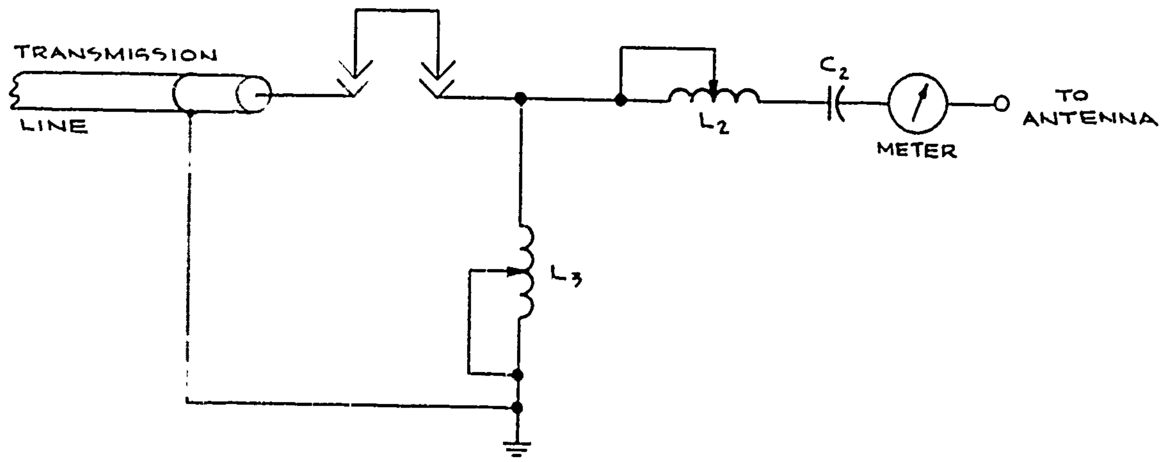


FIGURE D. 6

ANTENNA TUNING UNIT

INITIAL COIL POSITIONS FOR 4" DIAMETER COILS

frequency (kHz)	L_3 (# turns)	C_2 (μF)	L_2 (# turns)
600	17.5	.01	0
600	17.5	.005	14.5
800	15	.008	0
800	15	.005	10.5
1000	13.5	.006	0
1000	13.5	.003	11
1000	13.5	.015	15
1200	12	.005	0
1200	12	.003	10
1200	12	.0015	13
1400	11	.004	0
1400	11	.002	9
1400	11	.001	13.5
1600	10	.004	0
1600	10	.002	8
1600	10	.001	12

FIGURE D.7

INITIAL ADJUSTMENT OF L NETWORK

QUARTER WAVELENGTH HORIZONTAL WIRE ANTENNA

f. Repeat d and e until maximum current.

g. Repeat a through f until maximum current.

h. Re-tune transmitter and increase power as much as practical.

D.4 OPERATION

The operation of the expedient antenna is more critical than the normal antenna. Since the antenna is improvised it is readily subject to damage. The antenna should be inspected frequently. Since the transmitter is operating under abnormal conditions, the transmitter parameters should be monitored continuously to prevent damage.

If the emergency is not national, the Federal Communications Commission should be notified of the improvised operation as soon as practical. The broadcast of emergency information, however, takes precedence over requirements to notify the FCC.

After service is restored using the expedient antenna, the possibility of improving the efficiency of the antenna should be considered. The major improvement possible is to increase the height of the antenna above the ground. The higher the antenna, the stronger the radiated signal.